Journal

of

THE ROYAL AERONAUTICAL SOCIETY

JANUARY 1957

CONTENTS

FROM THE PRESIDENT

NOTICES

LESTER DURAND GARDNER—AN APPRECIATION
J. LAURENCE PRITCHARD

THE IMPORTANCE OF TIME IN AIRCRAFT MANUFACTURE
F. R. BANKS

METHODS OF REDUCING THE TRANSONIC DRAG OF SWEPT-BACK WINGS AT ZERO LIFT — D. KÜCHEMANN

ON THE NOISE FROM SUPERSONIC JETS — E. J. RICHARDS

TECHNICAL NOTES
Indicial Admittances for Linear Systems with Variable Coefficients—W. J. DUNCAN. Some Evaporation Measurements on Liquid Sprays—W. BERGWERK. Shock Load Tests of Anti-Vibration Mountings—ROLT HAMMOND. Note on a Short-Cut Method for Estimating Aircraft Direct Operating Costs—FRANK H. ROBERTSON. Note on the Bending of a Finite Parallelogrammic Plate under Continuous Non-Normal Loading: Erratum—K. I. McKENZIE and M. ROTHMAN.

GRADUATES' AND STUDENTS' SECTION

THE LIBRARY — REVIEWS — REPORTS

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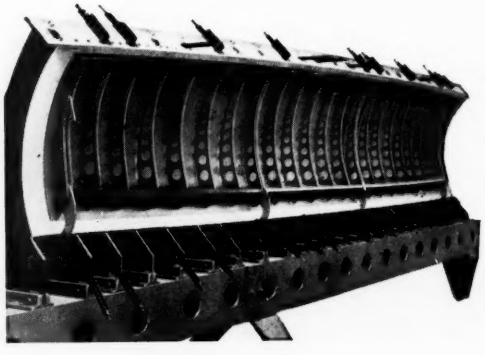

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Journal of

THE ROYAL AERONAUTICAL SOCIETY

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VOLUME 61 JANUARY 1957 NUMBER 553

CONTENTS

		PAGE
From the President		III
Notices		IV
The Presidential Address—The Weilberg Balloon Flight—Supplement to List of Members—Weather and Flight—Aeronautical Acoustics—Nominations for Fellowship of the Society—Diary—Associate Fellowship Examination, June 1957—Wright Brothers Lecture, 1956—Acknowledgments—Elections—News of Members—Annual Subscriptions—New Prices for Journal Binding—Changes of Address or Appointment.		
Lester Durand Gardner—An Appreciation	J. LAURENCE PRITCHARD	1
The Importance of Time in Aircraft Manufacture	F. R. BANKS	5
Methods of Reducing the Transonic Drag of Swept-Back Wings at Zero Lift	D. KÜCHEMANN	37
On the Noise from Supersonic Jets	E. J. RICHARDS	43
Technical Notes		46
Indicial Admittances for Linear Systems with Variable Coefficients—W. J. DUNCAN. Some Evaporation Measurements on Liquid Sprays—W. BERGWERK. Shock Load Tests of Anti-Vibration Mountings—ROLT HAMMOND. Note on a Short-Cut Method for Estimating Aircraft Direct Operating Costs—FRANK H. ROBERTSON. Note on the Bending of a Finite Parallelogrammic Plate Under Continuous Non-Normal Loading: Erratum—K. I. MCKENZIE AND M. ROTHMAN.		
Graduates' and Students' Section		54
The Library		55
REVIEWS: Theory and Practice of Lubrication for Engineers—Stresses in Aircraft and Shell Structures—Solutions of Problems in Aerodynamics—Solid Propellant Rockets—The Legal Status of Aircraft—Royal New Zealand Air Force—Engineering Dynamics—Proceedings of the Society for Experimental Stress Analysis, Vol. XIII, No. 2—Supersonic Inlet Diffusers and Introduction to Internal Aerodynamics—Handbook of Meteorological Instruments, Part 1: Instruments for Surface Observations—Aircraft Gas Turbines—Frequency Response—Numerical Analysis; with Emphasis on the Application of Numerical Techniques to Problems of Infinitesimal Calculus in Single Variable—History of the Second World War: "Administration of War Production"—The Design of Wing Sections—Performance Criteria of Gas-Turbine Combustion Chambers—Stability Functions for Structural Frameworks.		
ADDITIONS TO THE LIBRARY.	REPORTS.	

All communications for publication in, and advertisements for, the JOURNAL *should be addressed to the Editor,* JOAN BRADBROOKE, *A.R.Ae.S.; all communications on general matters affecting the Society should be addressed to the Secretary,* A. M. BALLANTYNE, *T.D., B.Sc., Ph.D., Hon.F.C.A.I., A.F.I.A.S., F.R.Ae.S.*

None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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The Royal Aeronautical Society

(Founded 1866)

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January 1957

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The Journal of the Royal Aeronautical Society

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

From the President

January 1957

TIME doesn't march on, it is we; and it is how we march and where we march that matters. We are apprentices, aeronautical engineers, physicists, mathematicians, aerodynamicists, chemists, pilots, metallurgists, navigators, instrument systems and electronic designers; and we are also Companions, Students, Graduates, Associate Fellows, Fellows and Honorary Fellows. On the one hand our endeavours are integrated and seen in the form of aerial vehicles, some of which are able to fly and some are not, and on the other hand together we form a Society for the "Advancement of Aeronautical Art, Science and Engineering".

We may work for a Military Service, the Aeronautical Industry, the Civil Service or the aerial transport corporations; and we may be in the Commonwealth of Nations or in one of many other countries, but whatever our job and wherever we are aeronautics will advance and our Society will prosper if our purpose is good.

You will be pleased to know that new members are enrolling at a quicker rate than ever before, that your Council is actively engaged in the formation of Sections to focus, when necessary, attention on new matters and that the staff are at all times anxious to help members with their problems.

1956 has been a good year for the Society. All New Years are full of promise and my message for 1957 is that we pull together to make it full of achievement.

E. T. Jones

NOTICES

An annual sum of £250 is available for premium awards for papers, including Technical Notes, published in the Journal. Members and non-members of the Society are invited to submit papers on any aspect of aeronautics

Presidential Address

Members are reminded that the President, Mr. E. T. Jones, C.B., O.B.E., F.R.Ae.S., will give his Presidential Address on 10th January 1957 at 6.30 p.m. at Church House, Westminster. Ladies are welcome to attend the Address. The President will talk of the aeronautical engineer, the world's newest form of transport and the oldest aeronautical Society. The Chair will be taken by Lord Brabazon of Tara, M.C., P.C., Hon.F.R.Ae.S.

Tickets are not required for the Presidential Address.

Following the Presidential Address a Reception and Buffet Supper will be held at Church House from 7.30-10.00 p.m. Dress will be dinner jacket or dark lounge suit. Tickets for the Reception, price £1 1s. 0d. each, are obtainable from the Secretary, 4 Hamilton Place, W.1.

The Weilberg Balloon Flight

On 7th November 1836 the "Royal Vauxhall Balloon" made an ascent from Vauxhall Gardens and the next day it landed in Weilberg, Nassau, having travelled 480 miles. The occupants of the balloon were Charles Green, Monck Mason and Robert Hollond, M.P.

This historic British flight far surpassed previous flights and the long distance record this accomplished stood until as late as 1907. To honour the event the balloon was renamed "The Great Balloon of Nassau."

The flight was commemorated by a series of six oil paintings by E. W. Cocks, most of the series being signed or initialled by him. Apparently the paintings were commissioned by Robert Hollond. They remained in the possession of the Hollond family until 1913 when they were disposed of by the nephew of the balloonist, John R. Hollond. The paintings then came into the possession of Sir Mortimer Singer, and in 1917 they were exhibited at the Grosvenor Gallery, London.

One of the paintings, "Leaving Dover" is now in the Science Museum, South Kensington, and a second, "Over the Medway," is in a private collection.

The remainder of the six paintings are now offered for sale. These are:

(1) "The Balloon in Flight" (canvas size 12 in. × 9½ in.)

(2) "The Take-off from Vauxhall Gardens" (29¼ in. × 23 in.)

(3) "Approaching Weilberg over Hilly Country" (18 in. × 24 in.)

(4) "The Balloon Dropping Anchor at Weilberg" (19 in. × 16 in.)

These four paintings commemorate an historic flight, and are a contemporary record of the event. If anyone is interested in them and wishes further particulars regarding probable price and where they can be viewed, will they please write to the Secretary of the Society who will give them the further particulars.

A photograph of the painting "The Balloon Dropping Anchor at Weilberg."

Supplement to List of Members 1955-6

With this Journal is issued a Supplement to the List of Members published with the Year Book 1955-6. This supplement includes an alphabetical list of members of the Society elected between 2nd September 1955 and 31st December 1956, a list by grades of transfers of membership during this period, a list of members who have been reinstated and a list of members who have died between 2nd September 1955 and 20th December 1956.

Nominations for Fellowship of the Society

The attention of Members is drawn to the following extract from the Society's By-Laws:—

"Fellows shall comprise every person who on the 30th day of January 1950 was on the Register as a Fellow of the Society; and every person thereafter awarded the honour of Fellowship.

"Elections to Fellowship will be made annually by the Council and will be announced at the Annual General Meeting of the Society. Nominations will be initiated by the members of the Council or by any four Fellows of the Society. It is the duty of the Council to see that the honour is awarded only to persons who have attained a considerable degree of technical eminence in the profession of aeronautics."

From this, it will be seen that any four Fellows may nominate a suitable candidate for Fellowship. Nominations for 1957 must be received by the Secretary before 31st January 1957.

DIARY

LONDON

10th January

PRESIDENTIAL ADDRESS.—E. T. Jones, C.B., O.B.E. Church House, Westminster, S.W.1. 6.30 p.m. Followed by a Reception for which tickets are required. *See* special notice.

17th January

SECTION LECTURE.—Electronic Control Techniques in Aircraft Manufacture. G. S. Kermack and H. Ogden. Library, 4 Hamilton Place, London, W.1. 7 p.m.

24th January

MAIN LECTURE.—Aeronautical Research in Holland. Prof. Dr. Ir. H. J. van der Maas. The Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea 5.30 p.m.)

29th January

SECTION LECTURE.—Design for Production. E. D. Keen. Library, 4 Hamilton Place, London, W.1. 7 p.m.

7th February

MAIN LECTURE AT HALTON BRANCH.—Synthetic Training Methods in Aviation. W. Makinson. The Canteen, Air Trainers Ltd., Aylesbury, Bucks. 6.30 p.m.

12th February

JOINT LECTURE WITH THE HELICOPTER ASSOCIATION OF GREAT BRITAIN.—Vibration Problems Associated with the Helicopter. O. L. L. Fitzwilliams. Library, 4 Hamilton Place, London, W.1. 7 p.m.

14th February

MAIN LECTURE.—The Fairey Delta. R. L. Lickley and L. P. Twiss. Institution of Mechanical Engineers, Birdcage Walk, London, S.W.1. 6 p.m. (Tea 5.30 p.m.)

26th February

SECTION LECTURE.—Recent Advances in the Design of Aircraft Tyres and Brakes. H. W. Trevaskis. Library, 4 Hamilton Place, London, W.1. 7 p.m.

GRADUATES' AND STUDENTS' SECTION

15th January

N. E. ROWE MEDAL COMPETITION.—Possible Flight Paths for Helicopters. P. F. Sutherby, Fins J. Wolkovitch. Library, 4 Hamilton Place, London, W.1. 7.30 p.m.

13th February

The Area Rule. W. T. Lord. Library, 4 Hamilton Place, London, W.1. 7.30 p.m.

BRANCHES

10th January

Bristol.—Design Problems of Modern Wind Tunnels. R. Hills. Conference Room, Filton House, Bristol Aeroplane Co. Ltd. 6 p.m.

Merthyr Tydfil.—Elements of the Aero Gas Turbine. S. L. Bragg. Teddington Aircraft Controls, Cefn Coed.

14th January

Henlow.—Aircraft Control. Prof. G. A. Whitfield. Bldg. No. 62, R.A.F. Technical College, Henlow. 7.30 p.m.

Southampton. Annual General Meeting and Film Show. Lecture Theatre, Institute of Education, University of Southampton. 7 p.m.

16th January

Christchurch.—Problems and Prospects in Civil Air Transport. P. G. Masefield. Town Hall, Christchurch. 7.30 p.m.

Leicester.—Agricultural Aviation. J. E. Harper, A.F.C. Lecture Theatre, Loughborough College, Leicester. 6.30 p.m.

Reading.—Film Evening. Western Manufacturing (Reading) Ltd. Canteen. 6 p.m.

17th January

Bristol.—Wind Tunnel Instrumentation. J. R. Anderson. Conference Room, Filton House, Bristol Aeroplane Co. Ltd. 6 p.m.

Isle of Wight.—Two Thousand Years of Aerodynamic Research. J. L. Pritchard, Hon. Fellow. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, E. Cowes. 6.30 p.m.

18th January

Birmingham.—Aerial Survey. Mr. Dawe. Birmingham Engineering Centre, Stephenson Place, Birmingham. 7.15 p.m.

20th January

Brough.—Gliding. J. C. Neilan. Lecture Hall, Yorkshire Electricity Board, Ferensway, Hull. 7.30 p.m.

24th January

Bristol.—The Application of Wind Tunnel Results to Aircraft Design. M. Wilde. Conference Room, Filton House, Bristol Aeroplane Co. Ltd. 6 p.m.

30th January

Preston.—Diving and Underwater Engineering. I. Fraser, V.C., D.S.O. R.A.F. Association, Preston. 7.30 p.m.

Southampton.—Atomic Energy for Aircraft Propulsion. J. E. Perkins. (Joint Meeting with the Institute of Production Engineers (Southern Section)). Lecture Theatre, Institute of Education, University of Southampton. 7 p.m.

Weybridge.—Electronics and the Aircraft Industry. Dr. C. F. Bareford. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

1st February

Chester.—Annual Dance. Quaintways Restaurant, Chester. 8 p.m. to 1 a.m.

Glasgow.—Pilcher Memorial Lecture. Civil Aviation in Scotland. Sir Patrick Dolan. Royal Technical College, Glasgow. 7.15 p.m.

4th February

Derby.—Annual General Meeting. Winning Papers of Ten-Minute Paper Competition. Rolls-Royce Welfare Hall, Nightingale Road, Derby. 6.15 p.m.

Henlow.—Annual General Meeting. Building No. 62, R.A.F. Technical College, Henlow. 7.30 p.m.

5th February

Boscombe Down.—Human Limitations of High Performance Flight. Gp. Capt. W. K. Stewart, C.B.E., A.F.C. Lecture Hall, A. & A.E.E., Boscombe Down. 5.45 p.m.

Bristol.—Joint Dance with the Institutes of Structural Mechanical, and Production Engineers, Ashton Court Country Club.

6th February

Chester.—Joint Meeting with Stanlow Branch of the Institute of Petroleum. Aircraft in the Oil Industry. Gp. Capt. Douglas Bader. Grosvenor Hotel, Chester. 7.30 p.m.

Christchurch.—Problems of Thermal Stressing. Prof. W. S. Hemp. King's Arms Hotel, Christchurch. 7.30 p.m.

Luton.—Production of Light Alloy Forgings. J. Crowther. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

Reading.—Aerial Survey. B. J. Attwell. Western Manufacturing (Reading) Ltd. Canteen. 6 p.m.

7th February

Cheltenham.—Problems of Progressive Failure. Sir Alfred Pugsley, O.B.E. St. Mary's College, Cheltenham. 7.30 p.m.

Halton.—MAIN LECTURE.—Synthetic Training Methods in Aviation. W. Makinson. The Canteen, Air Trainers Ltd., Aylesbury, Bucks. 7.30 p.m.

13th February

Leicester.—Flight Development of Modern Prototype Aircraft. C. F. Bethwaite. Lecture Theatre, Loughborough College, Leicester. 6.30 p.m.

15th February

Birmingham.—President's Night. DC-7 Film. High-Speed Flying. E. Gunn. Birmingham Engineering Centre, Stephenson Place, Birmingham. 7.15 p.m.

Brough.—Annual Dinner and Dance. Jackson's Ballroom, Hull.

18th February

Henlow.—New Methods of Approach to Airworthiness. W. Tye, O.B.E. Building No. 62, R.A.F. Technical College, Henlow. 7.30 p.m.

Diary continued

19th February

Belfast.—Lecture on Welding. K. A. Peel. Kensington Hotel, Belfast. 7 p.m.

20th February

Bristol.—Viscount. B. E. Stephenson. Conference Room, Filton House, Bristol Aeroplane Co. Ltd. 6 p.m.

Brough.—Prospects and Problems in the Use of Nuclear Energy. Prof. G. F. J. Garlick. Lecture Hall, Yorkshire Electricity Board, Ferensway, Hull. 7.30 p.m.

Manchester.—Flying Experiences. Capt. O. P. Jones, C.V.O., O.B.E. Reynolds Hall, College of Technology, Manchester. 7.30 p.m.

Southampton.—Branch Prize Papers. Lecture Theatre, Institute of Education, University of Southampton. 7 p.m.

Weybridge.—The Investigation of Aircraft Accidents. E. L. Ripley, O.B.E. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

21st February

Isle of Wight.—The Training of Aeronautical Engineers. Prof. A. R. Collar. Clubhouse, Sports and Social Club, Church Path, E. Cowes. 6.30 p.m.

Merthyr Tydfil.—Some Lubrication Problems. D. O. MacDougall, D.F.C. B.O.A.C., Treforest.

25th February

Glasgow.—Members' Night. Royal Technical College, Glasgow. 7.15 p.m.

27th February

Christchurch.—Lecture Competition. King's Arms Hotel, Christchurch. 7.30 p.m.

Preston.—The Investigation of Aircraft Accidents. E. L. Ripley, O.B.E., R.A.F. Association, Preston. 7.30 p.m.

Reading.—Boundary Layer Control and its Engineering Aspects. Dr. G. V. Lachmann and J. B. Edwards. Western Manufacturing (Reading) Ltd. Canteen. 6 p.m.

Associate Fellowship Examinations, June 1957

Entries for the next Associate Fellowship Examination should be received from Candidates in the British Isles by 28th February 1957. The closing date for entries outside the United Kingdom was 31st December.

Wright Brothers Lecture, 1956

Sir Arnold Hall, Vice-President, delivered the Wright Brothers Lecture to the Institute of the Aeronautical Sciences on 17th December 1956 in Washington. The title of his lecture was "Some Comments on Current Aviation Topics."

Acknowledgments

The Council acknowledge with grateful thanks the gift of old photographs from Mr. A. N. Jackson (*Associate Fellow*) and a selection of historical material from Mr. Geoffrey Dorman (*Associate*). They also thank Mr. John Thirkettle (*Associate Fellow*) for material for the Library.

Aeronautical Acoustics

A Second Course on Acoustics is to be held by the Aeronautical Engineering Department of the University of Southampton from 1st-6th April 1957. The Course is designed for people with no preliminary knowledge of Acoustics and is intended chiefly for those in the Aeronautical Industry, and other concerns, who have to deal with noise problems. Emphasis is laid on the mechanism of noise generation, a general background on the subject, and there are alternative advanced courses, one on the effect of noise on structures and one on noise measurement techniques.

The fee for the Course is £21 0s. 0d. including residence in one of the Halls of the University. Further details may be obtained from Mr. D. J. Mead, Aeronautical Engineering Department, The University, Southampton. Applications for the Course must be received by 1st March 1957.

News of Members

V. N. Bhardwaj (*Associate Fellow*), formerly at Air Headquarters, New Delhi, has now been posted to Hindustan Aircraft (P) Ltd., Bangalore, as Overhaul Manager (Aircraft).

Wing Commander R. L. Bloodworth (*Associate Fellow*) has retired from the Royal Air Force to take up an appointment with Rolls-Royce Ltd. He was formerly Chief Instructor, Aeronautical Engineering Wing, at Henlow.

A. J. K. Carline (*Associate Fellow*), formerly Chief Technician of Hunting Percival Aircraft Ltd., has been promoted to Deputy Chief Designer.

D. G. Dunphy (*Associate Fellow*), formerly at Headquarters Flying Training Command, is now Staff Officer (Technical) to the Deputy Director-General, Aircraft Research and Development, Ministry of Supply.

D. L. Fairweather (*Graduate*) is now employed as a Stressman in the grade of engineer at the Acton Design Office of English Electric Co. Ltd.

K. C. Garner (*Associate Fellow*) has taken up the post of Lecturer on Control and Simulation in the Department of Aircraft Electrical Engineering at the College of Aeronautics, Cranfield.

Maurice Jackson (*Associate Fellow*) has taken up a new appointment as Lecturer in Mechanical Engineering at Shrewsbury Technical College.

Squadron Leader L. C. James (*Associate Fellow*) has completed his tour of duty overseas and is now employed on Engineering duties at R.A.F., St. Mawgan.

J. Laver (*Associate*) is now a Designer in charge of design of Wind Tunnel Models and equipment for the Rolls-Royce tunnels at Hucknall and Derby.

Squadron Leader D. W. Morton (*Associate*) has retired from the Royal Air Force and has joined the Guided Weapons Division of the English Electric Co. Ltd. at Luton.

A. B. Naylor (*Associate*), formerly with B.O.A.C., London, as a Flight Engineer, is now a Technical Instructor for British West Indian Airways in Trinidad.

Group Captain V. C. Otter (*Associate Fellow*) has returned from R.A.F., Wildenrath, 2nd T.A.F., to take up the appointment of Command Engineer Officer at H.Q. Bomber Command, High Wycombe, Bucks.

D. A. Patterson (*Associate*) is relinquishing his position as Branch Manager of the Auckland Division of New Zealand National Airways to become Assistant to the General Manager at Wellington.

N. T. Scott (*Companion*), formerly Personnel Officer with Renold Chains Ltd., is now Secretary to the Careers and Appointments Board of the University of Nottingham.

B. R. Shelton (*Associate*), formerly Works Manager of the Electrical Section of Dowty Equipment Ltd., has been appointed Works Manager of Dowty Nucleonics Ltd.

I. Torbe (*Associate Fellow*), formerly Senior Lecturer at Loughborough College of Technology, is now a Lecturer in Aeronautics at the University of Southampton.

A. M. Uttley (*Associate Fellow*), formerly at the Ministry of Supply, is joining D.S.I.R. as Superintendent of the Control Mechanisms and Electronics Division at the National Physical Laboratory, Teddington, Middlesex.

Dr. E. W. C. Wilkins (*Associate Fellow*), formerly with the Technical Department of the Society, is now a Research Specialist in the Engineering Division, Lockheed Aircraft Corporation, Burbank, California.

Elections

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Sydney Edward Adams (*from Graduate*)
Denis Walter Barnes (*from Graduate*)
Fred Bradshaw (*from Graduate*)
Charles Carson Brodie (*from Associate*)
John Woodbury Bugler (*from Graduate*)
Bryan Sandford Clark
Anthony Lambert Cole (*from Graduate*)
Ronald Cole (*from Graduate*)
Arthur Haydon Craven (*from Graduate*)
Hugh St. Lawrence Dannatt
Andrew Fyfe Duncan (*from Graduate*)
Robert Edward Finch (*from Graduate*)
Cecil Frederick Stanton Fraser
John Alan Fuller (*from Graduate*)
Harry Ronald Harrison (*from Graduate*)
John Frederick Jones (*from Graduate*)
James Russell Leighton
Walter John Paul (*from Graduate*)
Tara Singh (*from Associate*)
Douglas Carl Stewart (*from Associate*)
Jeffrey Tinkler (*from Graduate*)
Joseph Zon

Associates

Gilbert Walton Aspin
George Henry William Banbury
James Kingsley Bell
Richard Joseph George Bray
William Gordon Burrow
Richard Carter
Desmond Alan Clifton-Mogg
John Robert Cowell
John Greig Dewar
Timothy Kay Dinsdale
Peter Reginald James Harding (*from Graduate*)
Eric Holman
Ralph Norman Hudson
Peter Edward Kenyon
Leonard William Kings
James Henry Lawrence
Harry Loads
Daniel McLaughlin
Peter Humphrey Marsom
Alfred David John Martin
Roy Albert Matson
Leslie Maxwell-Holroyd
David Ernest Mummery
Charles George Seymour Paterson
Kenneth Charles Plenty
John Desmond Russell
Norton Hume Smith (*from Companion*)
Richard Henry Trelease
Stewart Owen Tudor
Clifford John Turner

Graduates

Joseph Wolf Baumberg
John Michael Beaumont (*from Student*)
James Douglas Burley (*from Student*)
William Wallace Stewart Charters
John William Child
Graham Edward Cook (*from Student*)
David George Drake
Graham John Felton
Robert Frederick Howes
Thomas Johnston (*from Student*)
David Rupert Leonard
Hugh Anthony Money (*from Student*)
Michael Anthony Neal
Leslie Philip Pook
Geoffrey George Pope (*from Student*)
Armand Sigalla
Frank John Smithin
Brian Richard Songer
John Trevor Spafford
Peter Stafford
Malcolm John Terry
Geoffrey Roger Thornber
Peter Wentworth Throsby (*from Student*)
Alan Gerald Treasure (*from Student*)
Frederick James Tucker
Thomas Williams

Students

Adrian Brian John Arnold Barraclough
Michael Jeremy Bennison
Allan Baillie Blackley
Frank Melville Blows
John Bridgewater
Geoffrey Chisman
Raymond Michael William Cotton
Ivor Corkell
John Deakin
Oetarjo Diran
Alexander Hugh Campbell Fraser
Alan Frank Giles
Ian David Green
John Mervyn Greenwood
Henry John Hignett
Peter Barry Horsley
John Bruce Howard
Wojciech Joseph Iglinski
Christopher Jones
Patrick George Kalaugher
Jark Chong Lau
John David Ledger
Keith John Linder
Peter Alan Ling
Walter James Lyon
John Frederick McIntosh
Mohinder Singh Mahil

Students—Contd.

Vernon Marples
Donald Robert Maxwell
Cecil Stanley Morgan
Robert Harvey Crawford Naylor
Graham Arthur Nowell
Hedley Patrick O'Sullivan
Brian Ronald Perkin
David Alexander Robertson
David Fisher Shaw
Raymond Parmous Shreeve
Michael Richard Smith
Bohdan Solowij
Peter Sumner Stooks
Geoffrey John Sturgess
Raymond Geoffrey Styants
Brian Noel Swan
John Markland Threlfall
Roshan Lal Vij
August Christiaan Frederik Visman
Peter John Walker
William Heap Walmsley
Makhan Lal Wangnoo
Peter Miles Watkiss
John David Waud
Michael Robin Widdicks
Keith Wilkinson
Colin Brian Wills
Colin John Wood
Derek John Woolley

Companion

John Keith Yates (*from Graduate*)

Weather and Flight

A Residential Course lasting one week is to be held by the Field Studies Council, on Meteorology and Aeronautics, "Weather and Flight," from 3rd-10th July 1957 at Preston Montford Hall, near Shrewsbury. The Lecturers will be: Meteorology, Dr. R. S. Scorer, Imperial College, and C. E. Wallington, Meteorological Office; and Aeronautics, F. G. Irving, Imperial College. In addition there will be five special evening lectures and a visit on one day to a Gliding Club. The main course is intended to explain the basic principles, cloud physics and air dynamics and to interpret them in terms of the natural phenomena of weather and the artificial phenomena of flight. A knowledge of mathematics, although not essential, would be helpful.

The fee for the Course will be about £8 0s. 0d. Enquiries should be sent to: The Warden, Preston Montford Field Centre, Montford Bridge, Nr. Shrewsbury.

The Course has been organised jointly by the Field Studies Council and the Royal Meteorological Society, with the support of the Royal Aeronautical Society.

Annual Subscriptions

Members are reminded that their annual subscriptions became due on 1st January 1957. The rates are:—

	Home	Abroad
	£ s. d.	£ s. d.
Fellows	5 5 0	4 4 0
Associate Fellows	4 4 0	3 3 0
*Associates	3 3 0	3 3 0
Graduates (aged under 26)	2 2 0	2 2 0
Graduates (aged 26 and over)	2 12 6	2 12 6
Students (aged under 21)	1 1 0	1 1 0
Students (aged 21 and over)	1 11 6	1 11 6
Companions	3 3 0	3 3 0
Founder Members	2 2 0	2 2 0

*Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscription will be reduced by £1 1s. 0d. to £2 2s. 0d.

It will avoid delay and confusion if members, when sending remittances for subscriptions, will state their names clearly and give their addresses and grades of membership. Remittances should be made payable to the Royal Aeronautical Society.

New Prices for Journal Binding

We regret that because of increased costs in the printing and publishing trade during this past year, prices for the permanent binding of Journals have had to be increased for 1957. The new charges will be:—

Permanent Binding

1956 Volume (including packing and postage)	£1 2s. 6d.
Previous Volumes (including packing and postage)	£1 4s. 0d.

Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Members are asked to be certain that the address to which they want their Journals sent is the same on their letters to the Lewes Press and to the Society.

Self-Binder Cases

Self-Binder cases of the "Easibind" type to hold 12 Journals (cost 11s. 6d. each) are available from the offices of the Society.

Changes of Address or Appointment

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address. He would also like to know of any change of appointment.

When notifying changes please give the following particulars:—

Name (in block letters).	Grade of Membership.
New address (in block letters).	Old address.

New appointment.—Please give name and address of employer and position held.

Changes of address must be received *before the 15th of the month* in order to be effective for the JOURNAL for the following month.

The Journal of the Royal Aeronautical Society

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

VOLUME 61 JANUARY 1957 NUMBER 553

LESTER DURAND GARDNER

Honorary F.I.A.S., *Honorary Fellow*

(August 7 1876 - November 23 1956)

AT THE END of June 1939 Lester Gardner returned to New York from a visit to Europe and wrote a long personal letter to his many friends in America and other countries, telling them what he had been doing.

"I went to Europe," he said in this letter, "primarily to attend the Wilbur Wright Memorial Lecture and to see the beautiful new building of the Royal Aeronautical Society. This oldest of aeronautical societies has a new home which is so luxurious that it is breath-taking in both size and beauty."

Lester Gardner was not satisfied until the Institute of the Aeronautical Sciences, which he had founded and served so well, had its own beautiful new building for its headquarters in New York.

New York was his native city, where he was born, from which all his aeronautical activities originated, and where he died. For over forty years of his long, full, and interesting life, aviation was his only love.

He was trained at the Massachusetts Institute of Technology in engineering administration, and in administrative law at Columbia University. From 1901, for some years, he served on a number of American newspapers and magazines in Chicago and New York, an experience which was to prove of great value to him in later years.

Lester Gardner had a flair for publishing and publicity and in 1916 he founded *Aviation and Aeronautical Engineering*, with encouragement from three American aeronautical pioneers who were to become world famous, J. C. Hunsaker, Glenn Martin, and Grover Loening. All three were to play leading rôles in Lester Gardner's aviation projects in later years. Lester soon made a success of his new venture, a paper which still exists under the title *Aviation Weekly*. In 1928 he sold his interests in this and other papers, so that he could be free to devote himself to the larger problem of putting aircraft routes on the map of the world.

He had long been convinced, after seeing the Wright Brothers at the International Flying Meeting at Belmont Park, New York, in 1910, that world transport would be air transport, and he was determined to give all his energies to encouraging others to share in his belief.

In the early twenties it was difficult to persuade many aircraft manufacturers, let alone the man in the street, of the *tremendous* future the air held. It was confidently asserted by some that half a dozen firms could manufacture all the passenger aeroplanes likely to be required in the world for years ahead. The man in the street was more interested in the development of a cheap motor car, for that was something he could own and drive himself from door to door.

Photograph by Technology Review, Massachusetts Institute of Technology.

A photograph of Lester Gardner taken for his 80th Birthday, reproduced from the *Aeronautical Engineering Review* of the Institute of the Aeronautical Sciences, August 1956.

Lester Gardner grew up with American aviation and with those who became its leaders, so that he got to know every one who mattered in it. He made friends with them, sold them his ideas for putting aviation on the map, persuaded them to let him help, and cajoled them, in their prosperous years, to give money to help the Society he founded.

The year 1926 gave Lester Gardner an opportunity which he seized with both hands, to travel over the airlines of Europe. On his return from the trip in July, he came to London and the Society of British Aircraft Constructors gave him a lunch "to celebrate Lester Gardner's extraordinary airworthy feat." Among those present to meet him were many of the leading pioneers in British aviation.

"As one who has always been deeply interested in the development of aviation," he said at the lunch, "I thought it was up to me when I took a holiday in Europe to see for myself how aviation had developed there. In 53 flying days I have visited 27 countries and all the principal capitals in Europe, Northern Africa and Iraq, and I suppose I must have seen some million square miles of territory. On three consecutive nights I dined in Moscow, Berlin, and London respectively."

Moscow, Berlin, Northern Africa, Iraq! The names seem to strike a familiar chord thirty years after! Lord Thomson, the newly-appointed Chairman of the Royal Aero Club, added to the historic names by saying, when introducing the guest of honour, "We have much in common. We have both flown to Baghdad by the Desert Route, and we have both been to Bucharest." Lord Thomson, like many others present, had already met Lester in New York and had felt the impact of his outlook. Lester Gardner added, "My average speed had been about 90 m.p.h. and the flying time was 230 hours. I estimate that if I had travelled in the old fashioned way I would have had to spend some 900 hours in trains alone." Of the time saved by flying he afterwards coined the memorable phrase, "There is no way to travel as leisurely as by air."

For some 5,000 miles of his trip Lester took his wife Margaret, to whom, indeed, he owed the constant and tireless encouragement and help which enabled him to live twenty-five hours a day. Charles Grey wrote in *The Aeroplane*, as they were returning to New York, "One wishes them on behalf of the whole of the British Aeronautical community a safe journey and many years continuation of the good work which they have both done for International Aviation."

The following year Lester Gardner was back again in Europe to attend the Fourth International Congress on Civil Aviation, as an official American delegate appointed by the President, an appointment renewed for the Fifth Congress held in Washington in 1928. It was in the July of that year that I wrote to him and J. C. Hunsaker and sent them details of the work and objects of the Aeronautical Society, and its organisation. Both were anxious to see a similar society formed in the United States. Lester was then President of the Aeronautical Chamber of Commerce of America, and in a position to influence many who might help to found such a Society.

But the time was not ripe.

In 1929 Lester Gardner again came to Europe, this time as guest speaker at the International Advertising Convention held in Berlin and as American delegate to the Aero Exhibition at Olympia. That year he was elected an Associate Fellow of the Society and took away a dozen or so forms so he could get other Americans to join. Before he left England he took the opportunity to go to Hull and give a talk on the importance of Hull as an international airport of the future, on the route from the United States to northern Europe, urging the town to take the necessary steps as quickly as possible. An opportunity appears to have been missed.

In 1930, while I was on a visit to New York, Lester Gardner took the opportunity of calling a number of the American members of the Society together, and others in the industry, so that I could give them a first-hand account of the work of the Society. Just over twenty years later Lester sent to me a draft of the first chapter of the history of the Institute of the Aeronautical Sciences. The draft had been prepared by him and J. C. Hunsaker, two of the founders. I quote briefly.

"It was obvious that when an independent aeronautical society should be organized in the United States, the Royal Aeronautical Society could provide a general pattern of organization and operation. . . ." The draft of this preliminary chapter ended, ". . . the Institute was incorporated on a five cent standard form and by payment of the incorporating fee of $40. The expense of $40.05 was the total for the legal or other expenses of all the preliminaries to the first meeting of the incorporators on October 17, 1932."

Paul Johnston, the present Director of the flourishing Institute, on the occasion of Lester's 80th birthday in August 1956, paid him a moving tribute in the *Aeronautical Engineering Review*.

"We of the Institute owe much to Lester Gardner. He was the spark plug for that group of aviation people (including Hunsaker, Warner, Osborn, Loening, Wright, Doolittle, Aldrin, de Flores, and many others) who foresaw the need for a scientific and technical society for the aeronautical engineering profession and then undertook to *do* something about it. . . . In 1932 this was no easy task. . . . The country was in the throes of the most crippling economic depression of all time. . . . The number of shirt fronts he drenched with his tears, the number of desks he pounded to splinters, the number of doorbells he rang in those days he alone can tell. . . . He breathed life into the organization and pumped the essential plasma, dollar by dollar, into its veins to tide over a precarious infancy. For our very existence he must be given full marks."

In 1936, Lester Gardner flew from Lakehurst to Germany in the airship Hindenberg, and then by aeroplane to Moscow, setting up the quickest time from the United States to Russia. On his way back to the United States he was given the unusual, and indeed rare honour, of being the guest of the Royal Aero Club, the Society of British Aircraft Constructors and the Royal Aeronautical Society at dinner. He had then spent a month in Europe, attending the Lilienthal Gesellschaft, in Berlin; paying visits to Gottingen, Dessau, Milan, Rome, Guidonia, Cologne and Paris.

Lester was much moved by this dinner, arranged, by the way, on the initiative of Richard Fairey, and was especially pleased that one of the guests was F. W. Lanchester, who had made a special effort to come to London to pay honour to Lester.

Lester Gardner made a practice of writing letters following his major air trips, descriptive, historic, and fascinating. A set of these letters would prove of very high value to future aeronautical historians and it is hoped that a complete set has been preserved.

In 1939, he flew to Rome to attend the first World Congress of the Aeronautical Press, before attending the Wilbur Wright Memorial Lecture given by his friend George Lewis. From Rome he made a number of flying trips. I quote a brief passage from his 5,000-word letter.

"The flight from Rome to Athens has everything. Roman countryside, with its intense cultivation; many, many small cities with their beautiful cathedrals and graceful contours. . . . Soon the bleak hills of Albania could be seen on the left. Ahead was the Island of Corfu, which was to be our first Greek landfall. We were flying at 8,000 feet and within the next hour were to have an emotional experience that must come to anyone who sees for the first time in a very few minutes the home of Ulysses—that Mouse Island which is his vessel turned to stone—Mt. Parnassus with Thermopylae and Delphi at its base—the Bay of Arta where the battle of Actium was fought—Corinth and its canal; and before you can realise it you have flown in a few short hours from Rome to the centre of Grecian culture and history and are gliding to a landing at the Tatoi airport."

Earlier in the year he had been one of the passengers during the first week of flying over Trans-Canada Airlines from Montreal to Vancouver. He flew through the night and wrote, "The sky was so clear that we had a spectacular showing of the mysterious Northern Lights. The sky was literally dancing with them. I was fascinated watching them form one shape and then gradually change to another. The phenomenon was all around us and we passed an hour or two following the ever changing cloudlike masses forming and disintegrating like so much smoke in a fitful breeze."

Lester Gardner was flying in the days when one could get more out of the scenery below than is usual nowadays. Every one of his descriptive letters is full of details of interest.

"I have fortunately been privileged to fly over the Pyramids of Egypt, and by that I do not mean just those of Cheops," he wrote in another letter. "One afternoon on a flight from Aboukir near Alexandria, I flew over the Sahara and counted from my cockpit seat fourteen pyramids and the panorama included the Sphinx for good measure. A week later I flew over the ruins of Nineveh in the morning and in the afternoon flew over Babylon two hundred and fifty miles away. . . . I have seen the Coliseum and Forum of Rome from an Italian dirigible. I have also flown over the mysterious prehistoric Stonehenge in England."

He flew on all the routes over the Rockies and the Alps; over the jungles of Yucatan and the mysterious city of the Mayas; over Mexico, Cuba, Miami, and most parts of the United States visible from the air!

One more quotation from his letters. This was written about Croydon after his landing there from Europe in 1939.

"I recall the early days when it was small and did not have its present traffic nor traffic building which has served so many air travellers for the last ten years. We used to consider it a great achievement. Now it is a comparatively small air terminal having been outclassed by many more recent aerodromes. But the field was filled with familiar types. Douglas transports shining brightly in the sun were standing beside the great Handley-Page 'built in head winds' which are famous for their ten-year record of ferrying forty passengers a trip from London to Paris and back without an accident—and for making money for Imperial Airways. The good old Junkers 52 and the more recent English, French and German types were sunning themselves ready to wend their airways to all parts of the world."

At one time Lester was called The Flying Ambassador. Everywhere he went he made friends and introduced people to one another so they could make friends of each other and join the great Lester Legion of Friendship. He was a particularly close friend of so many in Great Britain, for which he always had a deep affection, for he was of British descent. He even managed to raise a fund in England to benefit the Institute! I remember how he persuaded Richard Fairey in 1939 to give him credit through the Aeronautical Society for £200, so that he could buy books for the Institute's library in New York!

Few people who have experienced Lester Gardner as an exhaustive, genial, imperative and generous host, will ever forget their experience. My own first one was in June 1930, in New York. I had telephoned to him at eight o'clock in the morning to tell him I had arrived. It was a fatal thing to do. He replied at once that he would be along in twenty minutes for breakfast with me, and would tell me the skedule he had arranged. I went to bed that midnight, after every minute of the day Lester had legislated for behind me—exhausted. The next morning he gave me the thrill of my life, the opportunity to watch Commander Byrd, fresh back from his Polar exploration, in the unbelievable ticker tape Parade which only New York can put on. I had been found a seat in the Mayor's stand

Major Lester D. Gardner presenting the Musick Memorial Trophy to Mr. (now Sir) Arthur Gouge in 1939.

and it was then I learnt that there were no doors Lester could not manage to open.

They were the days of Prohibition, and with three mysterious knocks at the end of an underground passage, whispered words through a grill, I found myself drinking an illegal bottle of British beer on a stool sitting between Lester and a New York cop complete with revolver and a glass of something which looked suspiciously like whisky! One does not forget these things, any more than I have ever forgotten a flight Lester arranged for me in a Sikorsky amphibian on the following day over New York. I was told by the pilot we could always glide down to the Hudson in case of trouble, so there was nothing to worry about though we were flying only a hundred feet above the Woolworth building. I could see nothing but jagged looking skyscrapers; certainly no river! Lester never let one go back to England without long lingering memories of people one had met, places one had been to, and things one had done.

Lester himself had a vivid and unexpected memory. I remember when George Lewis came over and gave the Wilbur Wright Lecture he wanted to go to the National Physical Laboratory at Teddington, and I took him there with Lester. We left there an hour earlier than we expected and Lester suggested we should go and look at Hampton Court. I had to explain I had not yet seen it. From that moment Lester took Lewis and myself in hand, became the professional guide, and told us what we were going to see and where we would see it when we arrived. He had made one previous visit to Hampton Court and had remembered! Of course, George Lewis was delighted! I think I had the last word, nevertheless, when I took them the following day to visit a friend of mine in Sussex who owned a house old enough to have a minstrel gallery and, at the bottom of the great garden, an old Roman well, still in use.

The two looked silently down the well for some minutes while their host casually talked about anything but the well, and Lester suddenly, solemnly, said, "Fifteen hundred years before Columbus, George."

Space will be given some day, I hope, to a full story of this great American. This is a brief record of what he was as I knew him. The Society awarded him its Honorary Fellowship in 1942, the fourth American to receive it. The first three were the Wright Brothers and J. C. Hunsaker. He was terribly proud of the honour. In 1947, he received the coveted Daniel Guggenheim medal "for outstanding achievement in advancing aeronautics, particularly for his conception and organization of the Institute of the Aeronautical Sciences."

This is not intended to be any more than a brief memoir of a man who did so much for Anglo-American friendship in the thirty years I knew him, who always held out the helping hand, who disagreed and wanted his own way, but gave you yours because he liked so much to give pleasure.

Like many others of his friends I wrote to him on his 80th birthday. He sent me two letters in reply. One had been typed, for, as he explained, he had over four hundred to answer "and you can see that it would put too much of a strain on your new octogenarian friend." The other was short, in very shaky handwriting, and was signed "As ever, but feebler, Lester."

His first letter was headed: "I love everything that's old; old friends, old times, old manners, old books, old wine."

That was Lester Durand Gardner.

J. LAURENCE PRITCHARD.

The Importance of Time in Aircraft Manufacture

by

F. R. BANKS, *Fellow*

(The Bristol Aeroplane Co. Ltd.)

The 999th Lecture to be given before the Royal Aeronautical Society "The Importance of Time in Aircraft Manufacture" by Air Commodore F. R. Banks, C.B., O.B.E., F.R.Ae.S. was given on 17th October 1956 at the Institution of Mechanical Engineers, Great George St., London, S.W.1. Mr. E. T. Jones, C.B., O.B.E., F.R.Ae.S., President of the Society, was in the Chair. Opening the meeting, Mr. Jones said:—

This evening marked the opening of the Society's 1956-57 Lecture season in so far as the London district was concerned. Actually, two Main Lectures had already been given at Branches; the first at Derby and the second at Henlow and at both there was a large and appreciative audience. It was gratifying that these early Main Lectures at the Branches had been received so well. He mentioned this because out of nine Main Lectures this session four were planned to take place at Branches, and that was quite an innovation. It was, he thought in 1948 that Council thought it would be a good thing if a few of the Main Lectures each session were held at the Branches and, so to speak, take the Society now and again to the Branches. He was sure they would agree that that was a good thing to do. There might be some present from the Branches and he had no doubt there would be reciprocal response in the Branches' members coming to lectures in London.

Now it was his pleasant duty to introduce their Lecturer. Actually of course he did not require any introduction. Air Commodore Banks, as they well knew, was a Lecturer of some importance. He had lectured many times to this Society and, indeed, to other Societies in other countries. He was a Fellow of their Society, a Companion of the Bath, an Officer of the Order of the British Empire and, what was a little more unusual in their Lecturers, he was a Commander of the French Legion d'Honneur and a Commander of the United States Legion of Merit. He had a particular distinction in respect of the subject he was speaking on tonight. He started life as an engineer. He then became an aviation fuels specialist. Then he became Director-General of Engine Production in the Ministry of Aircraft Production, and later changed from Production to Development and became Director of Engine Development in the same Ministry. He then went back to his first love, fuels, and returned again for sixteen months to the post of Principal Director of Engine Research and Development at the Ministry of Supply, when at that point of time this Ministry was rather hard put to get the right man in the right job. He was now a Director of The Bristol Aeroplane Company and was also on the Boards of Bristol Aero Engines Ltd. and Bristol Aircraft Ltd.

SINCE THIS IS more a lecture than the presentation of a paper on a specialised engineering subject, I have written in the first person. I should also say that the opinions expressed are my own and do not necessarily represent those of my Company.

You may ask why I have been chosen to speak on aircraft rather than on engines, but I can only refer you to the Lectures Committee for that answer. Probably it is because I know relatively little of aircraft and, therefore, can speak with the confidence and assurance usual in the ignorant!

As I have been particularly asked to talk on the importance of time in aircraft manufacture, it is pertinent to consider how time and opportunity have been lost in the past rather muddled decade. Therefore, what follows is not so much technical but a discussion on this period and how it has influenced our future in aviation.

I will deal with both the military and civil aspects, upon which latter our aviation future may largely depend.

Quality and Quantity

It is the new look in military aircraft since the last War, with the enormously increased (and still increasing) complexity in airframe, equipment and armament, which has made them so costly that they now absorb a large proportion of the available funds and manpower and set a severe limit to the numbers which can be ordered; and we run the risk of having only a token Air Force unless it is possible to devise some means of getting more of the things we really want.

Duplication of effort on the variety of aircraft and weapons at present under development should, wherever possible, be avoided or severely restricted to important projects having a number of "unknowns." Then there must be more certainty of having better performing aircraft, and getting them quickly into service—although one would think that present Government policy is to reduce the Royal Air Force to near impotency, both in quality and strength.

In quality of equipment the R.A.F. is about fourth

after America, Russia and Sweden. In quality of personnel, it remains first class.

The cause of our present condition is partly due to the inordinate time taken to issue an Air Ministry requirement where, literally, years have elapsed since the first thoughts, and not always the most timely aircraft or armament chosen. Also, the Aircraft Industry was not alive early enough to the implications of the new look in aircraft and failed to prepare itself for the much greater technical needs of the day.

The net result is that due to more or less indiscriminate ordering, "off the drawing board," very little has reached the production stage. Even some of the more straightforward projects have failed to attain their performance standards and have either had to be ordered only in very limited quantity (to give the Royal Air Force something) or have been finally cancelled.

I say "off the drawing board" since it is my firm conviction that, in recent years, the wind tunnel has not been sufficiently or adequately used to avoid some of the troubles we have been in with prototypes.

While I am aware that our bomber force must inevitably be much smaller than that represented by the U.S.A.F.'s Strategic Air Command and can provide only a limited contribution to the latter's strength, nevertheless, if we are to be fully effective, our V-Force should be similarly organised and always kept on a war footing—meaning intensive training and the active participation in "war" exercises, all involving considerable flying. If this is the right outlook then the normal run of mishaps in training, together with the necessary reserve aircraft, will demand a fair-sized Force and one which, I think, would be considerably larger than that at present contemplated.

I do not pretend to know the answers to all these problems; but if it is argued that we want quality rather than quantity (since nuclear warfare will be short if not very sweet), can it be said that we have the quality or even the bare minimum in numbers—knowing the heavy losses of War, however short-lived it may be?

Have we still to consider two additional types of bomber? It should now be possible technically to assess each and choose that showing the superior overall advantages and future "stretch" capabilities.

Operational Requirements and their Time and Timing

Much thought and effort go into a new operational requirement, to get it to a state acceptable for translation and transmission to the Industry. But with scientific and technical progress always a jump ahead of the final requirement, the difficulties of the Air Staff in coming to a firm and quick decision are clearly great; and all this, together with other "political" delays, risks the requirement becoming obsolete before the final design contract is issued and a line goes on the drawing board. In other words, it is the continuing flow of new ideas on aircraft and weapons that compounds the confusion of thought inevitably to delay decisions.

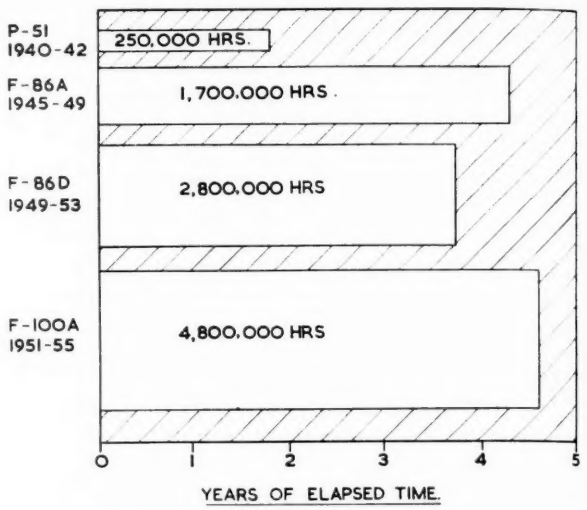

FIGURE 1.

Aircraft development trend. Calendar time and engineering manhours required from start of design to acceptance of 200th unit.

There has been considerable and unfavourable comment by the uninformed, also by the better informed, on the very heavy commitments of the Aircraft Industry and the time it takes to bring a fighter or bomber to production. And while a good deal of this criticism savours of hindsight (and this lecture is not in the nature of a witch-hunt), it seems to be quite commonly accepted that from seven to ten years are now required to design, develop and get a bomber to the production stage — but not necessarily into production.

The aim must be to cut this time factor almost in half if an aircraft is to be of any real use to the Royal Air Force; which can only be done by better research and experimental facilities and larger specialist technical and engineering staffs in the firms.

Our friends in the U.S.A. (with their vastly greater resources and large users) realised soon after the last War the significance of the then already increasing complexity of the military aircraft. As an illustration of this, Figure 1 gives the trend of aircraft development in terms of engineering manhours and calendar time required from the start of design to the acceptance of the 200th unit. I am indebted to North American Aviation for this data. I have also included some confirmatory data in Appendix I.

It will be seen that, in the case of the jet fighters shown, while the engineering manhours increased from 1,700,000 for the F-86A to 4,800,000 for the F-100A, the difference in elapsed time between the two basic aircraft types was only a matter of months.

In my opinion, when a requirement is issued by the Air Ministry to the Ministry of Supply the latter should select only one or two firms to tender for it. The previous practice, of letting all likely bomber (or fighter) builders tender, is not practicable today since

it ties up too many valuable technical staffs who should be doing other useful things, or re-distributing themselves and augmenting the technical and design departments of the more successful organisations.

But the first step in the ordering process of new weapon systems must be the creation of an adequate and efficient system of project evaluation. The assessment team for this purpose, which would be a mixed one of military and civil scientific personnel, should be located in the M.o.S. It must be the authoritative body, using the Royal Aircraft Establishment and others in an advisory capacity. Contracts should then be awarded, selectively, to those firms most likely to meet the commitments in reasonable time, avoiding consolation prizes, in the form of prototype and limited production orders, which have so often been given to the "second best."

As air defence, which is this Country's prime consideration, is infinitely more difficult than the attacker's role, it is not now sufficient (except for the "old fashioned" type of war) to order the odd fighter and leave it at that. Today, defence is a complex and highly integrated problem involving the combined directing or monitoring of piloted fighters and ground-to-air weapons against an attacker.

Therefore, in formulating a requirement the weapon(s) only cannot be considered by itself, but the whole problem must be put to the Aircraft Industry to solve in the best way possible. In other words, the requirement might be couched as follows: "to evolve a complete weapons system to intercept and destroy at (say) 50 miles from shore an attacker flying at a Mach No. of 2 at 70,000 feet."

This would involve completely co-ordinated "weapons system" groups within the firms tendering for the requirement, who would advise and then work hand-in-hand with the design staffs.

The only alternative is to use an outside "weapons management unit" of the type existing in the U.S.A., such as the Ramo-Wooldridge and Rand Corporations.

In my opinion, it is impracticable arbitrarily to consider (as voiced in some quarters) a banding together, by Government decree, of the various and individual firms into larger units. In other words, it is a "sink or swim" philosophy which should actuate Government procurement, and the weakest must go to the wall or accept work from the successful firms—either to supplement the production rate by building the complete machine or as sub-contractors for components.

The Americans have used extensively, both for aircraft and engines, the "shadow" and sub-contracting schemes—the former idea originating in this Country.

For instance, I know of one (parent) engine firm in the States which reached a peak production, during the period of the Korean War, of about 750 jet engines per month with an administrative, engineering and production total of only twelve thousand personnel. This was made possible by buying from specialist firms completely machined components, such as bladed turbine wheels and shafts and combustion-ware, etc.; and when production was cut, "in one fell swoop," to 100 units, or less, per month, it did not result in complete disorganisation within the Company, and not too large a mass of labour was thrown out of work in one area. In fact, the company has managed to keep employment at a reasonable level by applying for, and being awarded, a U.S.A.F. contract for repairing their own engines.

Anyway, American labour does not resist going to other areas for work so much as our own, although I agree that no one wants to change his home if it can possibly be avoided. But there has to be some flexibility in the movement of labour if we are to be competitive in World trade.

I understand that it is the deliberate policy of the American Department of Defense to "shadow" engine manufacture in peacetime, to avoid large manpower peaks and depressions in the parent companies and to have a war-potential source of supply. For instance, the Pratt and Whitney J57 is being manufactured by the Ford plant at Chicago and the Wright J65 (Sapphire) has also been built by Buick.

To return to my subject, and in retrospect: we have not anticipated or subsequently taken all steps to meet the increasing technical and engineering demands of modern aviation, and some of the more technically capable firms have become overloaded with projects while others seem to have little to offer.

If blame attaches to anyone for this lack of appreciation, then the Industry must share it with the Government Departments concerned; for it is the Industry who should have been on the alert and prepared itself to meet these heavier and much more highly technical commitments. In fact, the Industry only appears recently to have woken up to the fact that the wind tunnel is an indispensable piece of equipment—for much more intensive use than in the past, to ensure that the aircraft prototype, when built, will perform and handle as the designer intended without major and time-consuming modifications becoming necessary.

But all of us, in Government Departments and in the Industry, must share the responsibility for the present state of affairs.

Incidentally, a major cause of future delay in producing satisfactory supersonic prototypes on time can well be in the making of the wind tunnel model, unless there are new ideas on its design and manufacture. These models require considerable skill both in their design and manufacture; and some have taken a full year or more to make, being virtually tool-room jobs.

My experience, of about thirty years, has indicated that the successful aircraft and engine firms have usually been those who anticipated a need and came up with such an attractive proposal that it often formed the basis of an official requirement. This was certainly the case before and during the last War, but is virtually impossible nowadays due to the prohibitive cost of embarking upon any military project as a private venture.

An important point, and one not always appreciated by those outside the armaments industry, is that there is really no such thing as a firm "backlog of orders" when

holding Government contracts, since the Government (for political or other reasons) can reduce or cancel completely any such contract with little or no prior notice. This is another reason why firms tend to get overloaded with various projects; and they have to be very shrewd or very good at crystal gazing to know whether or not they are on a good thing. Therefore, they generally take on a number of projects, one or two of which, they hope, will eventually get into production.

There is lack of a good assessment team and a statistical and logistical section within the M.o.S., to analyse the results of a requirement, from the brochures submitted by the Industry, and to put a capability factor on each firm. I am aware that there already exist projects and plans sections (AD/RD Projects and T.D. Plans) who, with the various technical directorates, assess the designs and advise on their technical merits, etc.; but these sections are hopelessly understaffed and do not have the standing or authority which should be theirs.

What I wish to see is a single self-contained team whose job it is not only to assess new designs but to analyse the firms' capability to design, develop and produce aircraft or their equipment at the desired rate. And, incidentally, there is no need for the separate "empires" of aircraft and guided weapons within the M.o.S. These should be combined, in the interests of economy in personnel and funds.

In the last War, the Ministry of Aircraft Production had a statistical and planning department which, for some reason or other, was afterwards disbanded. It is urgently required today in order to give the lead on the proper use of manpower—to assess the manhours needed to build a prototype and to vet the Industry's productive capacity in these terms.

While a relatively small firm with limited but capable technical and engineering staff can design and manufacture a satisfactory prototype, in due course, much more is necessary; and there should be greater certainty than there appears at present of getting a successful prototype and clearing it to production in reasonable time. By "reasonable time" I mean five years and not seven or ten. A high supersonic aircraft may, however, take up to ten years.

It may be argued that the lack of proper facilities and equipment make this reduction in time impossible of achievement, but we cannot otherwise hope to compete in World aviation or afford the wasted effort in achieving the obsolete.

For the very reason that an aircraft takes so much effort to design and build, it is mandatory that any firm tendering for a contract has full facilities for completing that commitment. In other words, it should have adequate technical and engineering strength and testing facilities, with aerodynamic, mechanical and all necessary systems' test rigs, to ensure that the prototype will have the minimum of "tricks" when it flies and a high degree of operational reliability built into it from the start.

Military Procurement

In the case of military aviation: in recent years, the Air Ministry (Air Staff) and the M.o.S. have suffered from "restrictive practices," in that a requirement does not go from the former direct to the latter, for transmission to the Industry, but has first to be considered by the Defence Research Policy Committee (D.R.P.C.), the Air Defence Committee and, I believe, the Cabinet Defence Committee. It will be appreciated, therefore, that the chance of any decision being made at all is probably very small, and the chance of the right decision being made is practically zero. Even before these hurdles were placed between the Air Ministry and the M.o.S., the length of time taken by the Air Staff to issue a requirement was largely due to the delays in getting Treasury approval.

When considering the various projects which have been initiated since the end of the War, one cannot avoid the conclusion that the Air Ministry has not always had sound technical advice regarding the types of aircraft to order; and, presumably, it was such advice that caused *two* more advanced bomber prototypes to be put in hand. But, to get something more quickly, a less ambitious specification was implemented, *i.e.* the Valiant, which at the time of its conception represented a good start to the bomber programme. But still more chilly feet caused the Sperrin to be ordered, which was not, I believe, an Air Staff requirement. In fact, some of the projects of recent years bear the stamp of "hunches."

While the Sperrin might have been conventionally reasonable, there was no need for both machines; and the relative merits of delta and crescent wings could surely have been resolved in the wind tunnel. If it is contended that we then had no suitable wind tunnel to evaluate these designs, I think our American friends would have offered their facilities if approached.

All this is past history, but I mention it because we still appear to be living in the era between the two Wars and have yet to reach the stage of formulating an advanced and logical programme of research and development in line with the leading countries.

To speed up the clearance and issue of a requirement, the Ministry of Defence, only, as the top defence authority, should be brought into the military procurement picture, to assess and confirm the need, in the light of all other requirements, and then to clear its financing with the Treasury without delay.

The apparent intention of drastically reducing the size and scope of the armed forces of this Country might well allow the Admiralty (who mostly looks after its own procurement) and the War Office to handle their own non-aviation projects directly with the contractors concerned. But in the case of military aviation, the disproportionately large and costly effort which has to go into the whole aircraft procurement process, all of which is in a continual state of scientific and engineering flux, demands special supervision; and the engineering effort involved in getting a prototype manufactured and fully developed is many times that of producing such things as ships and tanks, etc.

Therefore, it might be feasible to consider the M.o.S. as a specialised kind of Ministry of Aviation. It could then be considerably reduced in size and so become more closely knit.

The " new look " M.o.S. or Ministry of Aviation, if formed, should be regarded as a top level administrative and technical organisation which could offer jobs at competitive salaries to a few senior administrators from the outside, to take key positions in the engineering and production sections. Since Ministries do not build things but only cause them to be built, we cannot afford to rob the Industry of too many able people or risk putting those available into positions which do not allow full use of their skill and experience. However, a few capable administrative engineers would be invaluable to such a Department.

In the case of civil aviation and because of the urgent need for the Country to be up with the leaders in air transport, there should be a more direct procurement link between the two national airlines (B.O.A.C. and B.E.A.) and the Aircraft Industry. But, to contribute effectively to any future new look in civil aviation, the technical and procurement departments of the airline companies would have to be considerably strengthened.

It is impracticable to consider entirely eliminating the M.o.S. (or Ministry of Aviation) in the procurement processes of civil aircraft since this Ministry is responsible for all research and development in aviation as a whole, including engines; which latter generally evolve as a result of a military need, are costly and difficult to develop, and should for economy of effort and financing remain with the Department.

Whatever the organisation, or reorganisation, I consider it most necessary that the operational requirements team at the Air Ministry and those concerned in the M.o.S., whose job it is to submit all requirements to the Industry, should be housed together in the same building, under one and the same Controller, that they may see each other daily and discuss together the various points of a requirement as it is being prepared. At the present time, the relevant sections and Departments concerned are sufficiently far apart for this to be difficult—which tends towards parochial viewpoints.

If I have laboured the importance of speeding the aircraft requirement, together with the need for realistic assessment of the firms' capabilities to design, develop and produce, it is because I feel so strongly that we must take less time to do things and have a better sense of timing; and we can only achieve this if we exercise superior technical judgment in what to go for and concentrate more effort upon each project.

Time and timing are the essence of success in aviation.

In order not to burden this lecture with statistical data, but because it is of interest and is worth close and concentrated study, I have reproduced in Appendix II some data on bomber production received from the Boeing Airplane Company. I have their permission to use this and record here my grateful thanks for the material.

I have chosen to record these various American data (North American and Boeing) because the two firms concerned have produced more fighters and bombers, respectively, than any others.

Civil Aircraft

Now, some remarks on civil aircraft. In this Country, with little internal air traffic but with lengthy communications and sea and air routes to all parts of the Commonwealth and the Empire, as well as to the rest of the World, we would appear to have all the encouragement and promise needed for our future in the air. But we do not have the domestic (military and civil) market of the United States, which in itself demands and absorbs a very large aircraft production (representing over 60 per cent of the World's civil aircraft requirements) and gives them an almost overwhelming advantage in acquiring elaborate production equipment and stabilising the industry at a good working (capacity) level.

In having two nationally owned airlines, who will at least give British aircraft first consideration, we are indeed lucky, since it is the only effective way of giving our aircraft manufacturers a start in civil aviation. But these two airlines do not represent, in size, a break-even market, unlike American operators who offer an enormous outlet for the U.S. aircraft industry.

In fact, were it not for the support of the Government in the past, in ordering prototypes and bearing largely the costs of their development, and also the encouragement of the two national airline companies, it would have been practically impossible for us to have attempted to compete in the civil aviation market. The cost of developing an engine alone would have prohibited this.

The American operators are well placed in the latter respect, since their large and comprehensive military programme eventually makes available well-developed engines mostly adaptable to civil use.

There is a minimum size or capacity for a firm producing civil aircraft if it is to meet the rate needed to execute orders in reasonable time, and also to cater for the individual customer's needs; and profitable manufacture will be very difficult to achieve if production (with about 50 per cent sub-contracting) is less than about 10 large (150,000-300,000 lb.) machines per month. This, in my opinion, is a realistic figure if we are to think of competing with the U.S.A., and calls for much larger production units if it is to be considered at all.

Also in the case of the smaller (100,000-150,000 lb.) jet aircraft at present in the project and design stages in America, one firm is planning to produce, at peak, 10 per month; and there are three other firms all equally large and capable.

These production rates cannot be achieved without the commensurate capital expenditure on the very expensive and elaborate tools and tooling of the type now in general use in the United States. In fact, it is hardly possible to attain the low structure weights and, equally important, the high degree of quality in the modern airframe without the large presses, the

" sculpturing " machines or skin millers, the stretch-forming equipment and, even, the automatic riveting machines which the American industry is employing today.

The basis for the outputs given above stems from the fact that customers cannot, in the tough competition of airline operation, wait unduly long for their aircraft; and delivery must also be gauged to produce a yearly total which will ensure reasonably rapid recovery of the development and tooling charges in a competitive sales price.

Before all this happens, there is much preparatory work to be done. First, there is the market research—to judge whether or not the proposed aircraft is of the right type and size. Then must come the decision to build a prototype, to prove the designed performance and constructional features. All this " costs the earth," but it is very difficult to sell anything off the drawing board in the open market unless the manufacturer either has a large background of experience, and success, in building civil aircraft or the machine is, more or less, a direct development of an already well-tried model. Although the trend is now to avoid prototypes, as such, and to regard the first machine built as the production model or pattern.

Accurate estimates of the design and engineering effort are needed, together with the time and cost of manufacturing the prototype and getting the production version through its C. of A. tests; and jigging and tooling must be put in hand early in the prototype stage in anticipation of sales and to ensure delivery dates being kept. The scheduling of delivery dates and giving the actual days of delivery, is a sign of efficiency.

The above procedure must be followed so as to determine the sales price and the number of machines to be sold to reach the break-even point. Then the airline operators can again be approached and signed up, after the necessary guarantees and warranties have been agreed.

Later, if a second wave of orders results from satisfactory operation, the " learning curve " factor and inflation will both operate to show whether or not the sales price can be lowered or must be raised.

The financial risk is too great in these days to embark upon the design, manufacture and development of a new (prototype) aircraft, even with Government help for these phases, if a " by guess and by God " attitude is taken; and unless the procedure outlined above is followed, the results will be chaotic and costly in the extreme.

What I am really saying is this: if we are to sell against America, and probably Russia, we have to get organised into larger technical and production units or give up the idea of meeting this heavy competition. But the market for large, high performance aircraft appears to have been filled for the next fifteen or twenty years.

This may seem at variance with what I have already said regarding the procurement of military aircraft (that if a firm produces a good prototype but has poor production facilities, the production rate may be supplemented by placing orders for complete aircraft with a less technically successful firm), but the case of the civil aircraft is rather different.

Since military aircraft have all their development costs defrayed by the Government and only partial support has so far been given to civil machines, sufficient profit must be made by the parent firm to cover some of the latter's development charges and leave a reasonably high proportion available to plough back, so as to proceed with the next step. Therefore, if other firms are brought in to supplement the parent firm's production (of complete aircraft) the profits will obviously be severely reduced, thus restricting the scope of the parent firm's future developments.

It may, however, be nationally necessary to adopt for civil aircraft the procedure I have already outlined for the procurement and manufacture of military machines, since the shift of emphasis from military to civil aviation makes more urgent the need for maintaining the stability of the Aircraft Industry as a whole; and it should in the long run prove more advantageous to meet our own civil needs than to pay out further dollars, even if the total number of aircraft built does not reach a normally economic figure. But with full Government support in meeting the design, development and tooling charges, it is a practical way of keeping an important industry alive and active—and ensuring a limited profit.

To the great credit of one British firm, it has sold a fairly large number of medium size propeller-turbine aircraft to some North American airline operators. This has created a precedent and greatly increased the prestige of our Industry as a whole. But we should not deceive ourselves that the American airline operators, in particular, will buy British in future unless we can continue to compete qualitatively and quantitively with U.S. constructors and offer something very attractive in performance and delivery—since the latter are already in the process of filling their gaps with a variety of large and small jet aircraft and a propeller-turbine machine.

All this is not despondency but realism, and a challenge to the Industry to put on a completely new look in preparation for the events of the next decade or two. And can anyone deny that we need an entirely new approach to the business of meeting the increasingly rigorous demands of aviation?

To my mind, our " new approach " should start with a good look at the methods of the American aircraft industry and then adapt and modify their techniques and procedures for our own needs.

We have not yet grown out of the stage of throwing a cocktail party, at the drop of a hat, for an " achievement " which should now be regarded as an ordinary job of work. In fact, we too often act like a bunch of enthusiastic amateurs.

Paraphrasing the Red Queen in " Through the Looking Glass ": we don't want to be a " slow sort of country " and in aviation we have to run very fast to stay in the same place, but twice as fast to be in the lead.

Engines

Coming now to the question of engines.

In the past, that is between the two World Wars, an

engine was created or evolved more or less directly as the result of an Air Ministry requirement, to meet military needs, and civil aviation then took a reasonably well-developed military model and used it in derated form.

This practice, with four important exceptions, has not substantially changed since the last War, but the cost of engine development is now so great that, without Government support, we could not remain in the strong position we are today—with British engines highly regarded by all and sundry.

It is a platitude to say that a strong and healthy engine industry is needed before the Aircraft Industry can exist; and while this has long been recognised it has not always been easy, due to the enormous outlay necessary to maintain a comprehensive programme of engine development in anticipation of future needs.

The cost of designing, developing and bringing a large turbo-jet of, say, 15,000 lb. thrust to production is in the order of £8,000,000 over, about, a 5 year period.

Between the two Wars, it was usual to see an engine well on in its development before the airframe to take it was built. This was because 4-5 years were needed to get a piston engine to Type Test standard and into initial production. The aircraft was then designed around the new engine, or one which already existed.

The same general procedure holds good today, but with the difference that the timing and matching for the engine and aircraft combination must be much more accurately assessed and more closely co-ordinated.

While the engine has still to lead the aircraft, in conception and development, this lead time is not so great as it used to be, for the reason that the modern aircraft now takes about as long as the engine to design, build and test—even longer in some cases! Due to this, and also because the engine must be more completely integrated with (or within) the airframe design, for the reason of the greatly increased performance offered by the gas turbine (turbo-jet), the aircraft designer gets off to an early start on his new machine, but always with a known engine concept—if no fully developed engine already exists.

Therefore, while the trend of aircraft design would now appear to exercise much greater influence upon engine shape, size and performance than in the past, I doubt if the original practice will be reversed. There have, indeed, only been one or two cases of an engine designed and built for a particular aircraft, and these have not enjoyed success.

Now a word of warning on a situation which may threaten the future of some engines.

Due to protracted aircraft development and the small amount of flying put in by various aircraft in recent years, the development of the engine is in turn being seriously affected. Long-drawn out and intermittent flight testing can "snowball" into further delay with the tardy appearance of previously unsuspected engine trouble, which will throw out of gear and further prolong the flight-testing programme.

Added to this is the time taken to build some aircraft, where engines wait for installation in an airframe which is still years away; and the weight growth which often occurs in the design stages of an aircraft, due to poor weight control or altered requirements, may demand more thrust—thus absorbing further time and effort. So it can go on, in an ever-mounting spiral of time.

I mentioned earlier that there were four important exceptions to the rule that civil engines generally stemmed from military types. These are, the Dart, Proteus, Eland and Tyne; and although the former was originally ordered for a Royal Air Force trainer (the replacement of the Harvard), it was not used for that purpose but found its valuable niche in civil aviation.

This does, however, raise the important point of how to accumulate flight hours on a civil engine without a military application; because there has not been, until recently, a Service requirement for propeller-turbine aircraft. In fact, the Britannia will be in civil operation well ahead of the military transport version for the Royal Air Force.

In this connection, the M.o.S. has been very helpful in loaning flying test beds for the development of civil engines.

I mentioned earlier the impracticability, today, of duplicating designs to meet a given aircraft requirement. But this does not necessarily apply to the engine, which still requires a high degree of engineering art and considerable "know-how" to meet the ever-increasing demands for improved performance; and since there are different ways of getting better performance, it is not prudent to depend only upon one.

In the engine industry, we have the greatest asset and contribution to our strength and prosperity in aviation; and all this could vanish almost overnight and the Industry as a whole be made bankrupt by any false moves, made in the name of national economy, to reduce the scale of effort—which is already being jeopardised by a slow-moving aircraft situation.

America is not now behind us and has one or two good engines, even if all her engine firms do not measure up so closely, one to the other, as ours.

We are also at some disadvantage compared with the American engine industry; with their large military and civil production, and with so many aircraft flying, the U.S. engine builder is presented with a statistical appraisal of the behaviour of his product which is quite impossible otherwise to obtain.

It is therefore extremely important that, because of small production, our engine bench and flight development be sufficiently rigorous and realistic to ensure the maximum possible reliability in service. In other words, the need for maintaining our reputation for high individual quality of product was never more necessary. But all this does tend to keep the cost of the individual engine disproportionately high, because of lack of real production numbers.

The American engine builders have elaborate facilities for testing gas turbine engines at altitude conditions, closely simulating those of flight. Supplementing such plant in the individual firms is similar equipment available through the U.S.A.F., the Navy and

N.A.C.A.; and while some here have questioned the need for these facilities, and have said that their use had not resulted in superior compressor or engine performance, the lack of them might have produced much inferior engines. Further, it is practically impossible to know beforehand how an engine is likely to perform in an aircraft flying at, say, 60,000-70,000 ft., at a Mach number of 2·5-3, without such facilities; and it will be risky and somewhat late to wait until the actual aircraft (which has cost millions of manhours to engineer and manufacture) is ready to fly.

Analogue and digital computors are considered indispensable by the American aircraft industry, and all the engine builders, without exception, use these electronic mathematical aids extensively. Their use does not reduce the need for technicians, rather the reverse, but the operation of the equipment by skilled and knowledgeable personnel eases the load on the individuals in the design and performance calculating teams and allows an enormously increased volume of work to be done, thus expediting the whole design process and ensuring greater certainty in the rightness of choice of the final engine (compressor) design. In fact, to enable better engines to be evolved.

One engine company told me that the very full use they made of this equipment had cost them $1.5m. last year, and I know others paying more than this for the lease of such equipment.

The Future

What then is to be the pattern of British aviation?

We should take the *realistic* view that it would be unrealistic to attempt to compete with America in the scope, variety and size of their various projects. But, with full Government support, we can meet our own and also some of the World's needs in military and civil aircraft and in engines. Whether we could "leapfrog" the large subsonic civil jets and go for a supersonic machine is a moot point, but it would require an expenditure in money and time of at least £50m. (for design, research, two prototypes and production tooling) and 10 years to do this; and it could be a disastrous waste of effort if it did not come off or was mistimed.

There is, however, still scope left for our engineering ingenuity in the field of small and moderate size (up to 150,000 lb.) machines; and, following the Duke of Edinburgh's suggestions in the Tenth British Commonwealth and Empire Lecture, go wholeheartedly into the business of assessing, and then meeting, the needs of the specialist operator.

If the "non-scheduled" or independent operators, as legitimate competitors to the national airlines, were brought into the fold this would open up a more worthwhile market for our constructors.

Militarywise, we should have the supersonic bomber and I.C.B.M. (Intercontinental Ballistic Missile), even if we can only afford to develop one design off each. There is also the air defence fighter and the military transport.

In the case of engines, we must go all out to compete with America and Russia in quality and performance; and, having gone so far as a leader in aircraft propulsion, we cannot now afford to stand still or "die on our feet." But if our military and civil aircraft effort is allowed to go downhill, the effect on the engine industry will be serious.

A Recommendation

Before closing, I wish to amplify some of my earlier remarks regarding the need for more efficient and expeditious handling of a requirement by the Air Ministry. One of the difficulties in this connection is that the average General Duties officer who is appointed to these important (operational requirements) positions necessarily does not have a high degree of technical knowledge—excellent operational officers as all Royal Air Force personnel are. And there is lack of continuity, since they are never kept in these positions for a sufficient length of time to see their work progressed through to any real degree of finality.

There should be a corps of engineering officers of the highest technical qualifications (Shrivenham standards) who would be the "continuity sisters" to the G.D. officers in control; and with engineering officer personnel there could, perhaps, be formed an Air Materiel Command, on the lines of that in the U.S.A.F.

Conclusion

I am convinced of my thesis, of the need for cutting the gestation period of an aircraft by 50 per cent; and, indeed, one does not have to be a genius to see that there has been something amiss since the War, with the bright spots as rare exceptions. But it is only possible properly to judge and assess our true position by visiting other countries, which I have been doing for many years. We of the Industry should be able to look at ourselves critically, and it does no good in the present situation to shy away from the facts.

I did not go on the recent trip to Russia, but it is written plainly that, apart from their extraordinary advances in military aviation since the War (when their aviation effort was not a serious factor), the Russians will eventually be competing in the field of civil aviation with subsidised prices and good deliveries.

Something, therefore, has to be done quickly to get us out of what is really a pre-war state of mind, and one feebly grappling with problems far transcending anything of that time or even of the war period. But the answer is not to be found by making a series of drastic cuts, apparently now being considered and, possibly, already put into effect since writing this lecture. Arbitrary cuts are of little use and, indeed, can be completely destructive to an industry which is always delicately poised between prosperity and the "bread-line", and upon whose technical and engineering ability the Nation's safety so much depends.

The only way to avoid permanent injury to the Industry is by reappraisal of the existing projects, full support of civil aviation for all well-considered projects

within the Industry's capability, and a stable Government (Treasury) policy which will see an agreed programme through to fruition without frequent financial hindrance.

The drastic reductions which are threatened for the defence budget, and which may result in the literal carving up of our armed forces to quite ineffective strengths, savour of the traditional British outlook or frame of mind reasserting itself in high places—that, "war may never happen"; forgetting that the reason for the recent international "get-togethers and back-slapping" is that both sides have the nuclear weapon and the means of delivering it.

We enjoy at least the second highest standard of living in the World, but a Welfare State, like any other State, will cease to exist if it is not prepared to defend itself—as I think history can show. If the emphasis is on good living rather than on defending the way of living, the State is on very shaky foundations.

It must be realised that, while we were as efficient as the U.S.A. in producing airframes and engines (in lesser quantity) in the war period of 1939-45, there has since been a big change in the conception and production of the modern aircraft, which now demands *all* "the (new) tools of the trade", and the equipment previously mentioned is now really necessary for the production of safe, efficient and low-weight airframes of the size (capacity) now considered reasonable for long-range economic operation—also to conserve manpower.

The lesson we should have learned from this past decade, albeit somewhat late, is that aviation has grown into big business and serious business, and that it cannot be run by a few people with ideas. It needs considerable foresight, first class organisation and the elaborate facilities mentioned to get anywhere at all. But we can, and must, find a new formula in aviation by our undoubted engineering ability, always remembering that what still matters is to sell and to produce efficiently.

ACKNOWLEDGMENTS

I would thank my firm, The Bristol Aeroplane Company, for their permission to present this lecture, and also my secretary, Miss Carpenter, whose fingers and eyes have suffered great strain from the number of times she has had to re-type it.

I also wish to thank the Boeing Airplane Company and North American Aviation for data contained in the paper and in Appendix II.

APPENDIX I

SOME DATA TAKEN FROM THE TESTIMONY OF

LT. GENERAL DONALD L. PUTT

before the

SUB-COMMITTEE ON THE AIR FORCE

of the

COMMITTEE ON ARMED SERVICES

UNITED STATES SENATE

MAY 16, 17, 18 and 22, 1956

Since I have made frequent mention in my lecture of the enormously increased complexity of the modern military aircraft, I thought some figures from General Putt's testimony at the above hearing might be interesting and confirmatory.

The wind tunnel and engineering hours for the F-51 (Mustang) and F-86 were 2,077 and 66,776 respectively—or an increase of thirty-two times. Those for the F-100 totalled 168,000 manhours.

The engineering manhours (to first flight of the prototype) for the F-51 were 154,000, for the F-86 = 1,132,000 and for the F-100 = 4,040,000. There was a difference of seven years between the introduction into operational service of the F-51 and the F-86, and five years between the F-86 and the F-100. But, in the former case, this represented a difference between an old generation and an entirely new generation of aircraft.

The bare airframe costs of the F-51, F-86 and F-100 were: $26,841, $121,000 and $486,000 respectively.

In the case of bombers: the first B-17 (Flying Fortress) was built by Boeing, as a p.v., and cost them $500,000; but the prototype B-52, built by the same company, has cost about $50m.

APPENDIX II

NOTE:—There are one or two unfamiliar terms on the attached charts, and their meanings are given herewith:

G.F.A.E. = Government Furnished Airborne Equipment.

A.M.P.R. = Aeronautical Manufacturer's Planning Reports, which were approved by BuAer and A.M.C. (Air Materiel Command) on 3rd August 1953 and upon which is based the method for defining bare airframe weight.

Inplant = Parent Company's plant.

Vendor(s) = In this case, means the direct sub-contractors to the Parent Company.

BOMBERS

CUMULATIVE AVERAGE TOOL AND PRODUCTION HOURS PER A.M.P.R. POUND

100 PER CENT AP

Model	*Tool Hours/lb.*			*Prod. hrs. per lb.*	*Total tool and prod. hrs./lb.*	*Total non-recurr. tool hours*
	Non-Recurring	*Recurring*	*Total*			
B-17						
AP lb. 1	63·74	0·70	64·44	14·00	78·44	1,380,000
1-10	6·37	0·48	6·85	10·47	17·32	(21,650 lb.)
1-50	1·27	0·33	1·60	6·88	8·48	
1-100	0·64	0·27	0·91	5·51	6·42	
1-500	0·12	0·15	0·27	3·11	3·38	
B-29 Wichita						
AP lb. 1	159·81	2·50	162·31	17·50	179·81	7,687,000
1-10	15·98	1·80	17·78	12·61	30·39	(48,100 lb.)
1-50	3·20	1·25	4·45	7·62	12·07	
1-100	1·60	1·02	2·62	5·81	8·43	
1-500	0·32	0·66	0·98	2·70	3·68	
B-47						
AP lb. 1	157·63	2·08	159·71	15·99	175·70	8,830,000
1-10	15·76	1·38	17·14	11·35	28·49	(56,016 lb.)
1-50	3·15	0·80	3·95	7·03	10·98	
1-100	1·58	0·61	2·19	5·48	7·67	
1-500	0·32	0·31	0·63	2·92	3·55	
B-52						
AP lb. 1	142·25	4·97	147·22	13·80	161·02	16,053,000
1-10	14·23	2·99	17·22	8·80	26·02	(112,854 lb.)
1-50	2·85	1·44	4·29	5·09	9·38	
1-100	1·42	1·00	2·42	3·88	6·30	
1-500	0·29	0·40	0·69	2·00	2·66	

MODEL B-17

USEFUL LOAD $/LB./MILE/HOUR

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

AP'S	*Indexed to 1952 rates*			*Actual rates*		
	Non-Recurring	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	8·78			2·94		
Ave. 1-10	0·88	0·57	1·45	0·294	0·204	0·50
Ave. 1-50	0·18	0·52	0·70	0·06	0·18	0·24
Ave. 1-100	0·09	0·49	0·58	0·03	0·175	0·205
Ave. 1-500	0·02	0·36	0·38	0·006	0·153	0·159

Note: Useful load = 10,000 lb. Cruising speed = 196 miles/hour

MODEL B-17

USEFUL LOAD $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

AP's	*Exp.*	*Indexed to 1952 rates*			*Actual rates*		
		Non-Recurring	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	220·0	1,722·0			57·7		
Ave. 1-10	22·0	172·2	113·0	285·2	11·5	40·0	97·7
Ave. 1-50	4·40	34·4	102·0	136·4	5·8	37·5	49·0
Ave. 1-100	2·20	17·2	96·0	113·2	1·2	36·0	41·8
Ave. 1-500	0·4	3·4	70·5	73·9	576·5	30·4	31·6

Note: Useful load = 10,000 lb.

MODEL B-17

GROSS WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

		Indexed to 1952 rates			*Actual rates*		
AP's	*Exp.*	*Non-Recurring*	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1		405·86			135·88		
Ave. 1-10	5·2	40·6	31·0	71·6	13·6	11·3	24·8
Ave. 1-50	1·0	8·1	27·5	35·6	2·7	10·2	12·9
Ave. 1-100	0·5	4·1	24·5	28·6	1·4	9·2	10·6
Ave. 1-500	0·1	0·8	16·7	17·5	0·3	7·2	7·5

Note: Gross weight = 42,427 lb.

MODEL B-17

CONTRACTOR FURNISHED WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

	Indexed to 1952 rates			*Actual rates*		
AP's	*Recurring*	*Non-Recurring*	*Total*	*Recurring*	*Non-Recurring*	*Total*
Ave. 1		795·4			266·3	
Ave. 1-10	43	79·5	122·5	11·5	26·6	38·1
Ave. 1-50	39	15·9	54·9	11·2	5·3	16·5
Ave. 1-100	35	8·0	43·0	10·4	2·7	13·1
Ave. 1-500	23	1·6	24·6	8·0	0·5	8·5

Note: Contractor furnished weight = 21,650 lb.

MODEL B-29

USEFUL LOAD $/LB./MILE/HOUR

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

	Indexed to 1952 rates			*Actual rates*		
AP's	*Non-Recurring*	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	4·283			1·83		
Ave. 1-10	0·428	0·233	0·661	0·183	0·094	0·277
Ave. 1-50	0·086	0·166	0·252	0·037	0·075	0·122
Ave. 1-100	0·043	0·142	0·185	0·018	0·068	0·086
Ave. 1-500	0·009	0·095	0·104	0·004	0·051	0·055

Note: Useful load = 50,332 lb. Cruising speed = 253 miles/hour

MODEL B-29

USEFUL LOAD $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

		Indexed to 1952 rates			*Actual rates*		
AP's	*Exp.*	*Non-Recurring*	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	424·8	1,083·5			463·0		
Ave. 1-10	42·5	108·4	59	167·4	46·3	23·8	70·1
Ave. 1-50	8·5	21·7	42	63·7	9·3	19·0	28·3
Ave. 1-100	4·3	10·8	36	46·8	4·6	17·1	21·7
Ave. 1-500	0·9	2·2	24	26·2	0·9	12·8	13·7

Note: Useful load = 50,332 lb.

MODEL B-29

GROSS WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

		Indexed to 1952 rates			*Actual rates*		
AP's	*Exp.*	*Non-Recurring*	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	178·1	454·50			194·20		
Ave. 1-10	17·8	45·5	25·0	70·5	19·4	10·0	29·4
Ave. 1-50	3·6	9·1	17·7	26·8	3·9	8·0	11·9
Ave. 1-100	1·8	4·6	15·0	19·6	1·9	7·2	9·1
Ave. 1-500	0·4	0·9	10·0	10·9	0·4	5·4	5·8

Note: Gross weight = 120,000 lb.

MODEL B-29

CONTRACTOR FURNISHED WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

	Indexed to 1952 rates			*Actual rates*		
AP's	*Non-Recurring*	*Recurring*	*Total*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	1,133·83			484·50		
Ave. 1-10	113·4	52·0	165·4	48·5	17·5	66·0
Ave. 1-50	22·7	34·3	57·0	9·7	13·3	23·0
Ave. 1-100	11·3	27·7	39·0	4·8	11·5	16·3
Ave. 1-500	2·3	16·2	18·5	1·0	7·8	8·8

Note: Contractor furnished weight = 48,100 lb.

MODEL B-47

USEFUL LOAD $/LB./MILE/HOUR

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Exp.*	*Total Non-Recurring*	*Recurring*	*Total*
Ave. 1	0·278	1·978		
Ave. 1-10	0·028	0·198	0·081	0·279
Ave. 1-50	0·006	0·040	0·057	0·097
Ave. 1-100	0·003	0·020	0·049	0·069
Ave. 1-500	0·001	0·004	0·032	0·036

Note: Useful load = 103,227 lb.

MODEL B-47

USEFUL LOAD $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Exp.*	*Total Non-Recurring*	*Recurring*	*Total*
Ave. 1	179·9	1,279·5		
Ave. 1-10	18·0	128·0	52·3	180·3
Ave. 1-50	3·6	25·6	36·8	62·4
Ave. 1-100	1·8	12·8	31·4	44·2
Ave. 1-500	0·4	2·6	20·7	23·3

Note: Useful load = 103,227 lb.

MODEL B-47

GROSS WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Exp.*	*Total Non-Recurring*	*Recurring*	*Total*
Ave. 1	100·4	691·6		
Ave. 1-10	10·0	69·2	29·2	98·4
Ave. 1-50	2·0	13·8	20·5	34·3
Ave. 1-100	1·0	6·9	17·5	24·4
Ave. 1-500	0·2	1·4	11·6	13·0

Note: Gross weight = 185,000 lb.

MODEL B-47

CONTRACTOR FURNISHED WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Exp.*	*Total Non-Recurring*	*Recurring*	*Total*
Ave. 1	278·5	2,149·4		
Ave. 1-10	27·9	214·9	80·0	294·9
Ave. 1-50	5·6	43·0	51·0	94·0
Ave. 1-100	2·8	21·5	41·0	62·5
Ave. 1-500	0·6	4·3	24·0	28·3

Note: Contractor furnished weight = 58,465 lb.

MODEL B-52

USEFUL LOAD $/LB./MILE/HOUR

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	1·666		
Ave. 1-10	0·167	0·100	0·267
Ave. 1-50	0·033	0·059	0·092
Ave. 1-100	0·017	0·049	0·066
Ave. 1-500	0·003	0·032	0·035

Note: Useful load = 225,390 lb.

MODEL B-52

USEFUL LOAD $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP'S	*Exp.*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	299·1	1,132·8		
Ave. 1-10	29·9	113·3	68·3	181·6
Ave. 1-50	6·0	22·7	40·4	63·1
Ave. 1-100	3·0	11·3	33·3	44·6
Ave. 1-500	0·6	2·3	21·7	24·0

Note: Useful load = 225,300 lb.

MODEL B-52

GROSS WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Exp.*	*Prod.*	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	172·87		654·7		
Ave. 1-10	17·3	48·2	65·5	39·5	105·0
Ave. 1-50	3·5	9·6	13·1	23·3	36·4
Ave. 1-100	1·7	4·9	6·6	19·2	25·8
Ave. 1-500	0·4	0·9	1·3	12·6	13·9

Note: Gross weight = 390,000 lb.

MODEL B-52

CONTRACTOR FURNISHED WEIGHT $/LB.

INCLUDING EXPERIMENTAL AND ALL NON-RECURRING COST IN 1ST POSITION

Indexed to 1952 rates

AP's	*Non-Recurring*	*Recurring*	*Total*
Ave. 1	1,954·0		
Ave. 1-10	195·4	109·0	304·0
Ave. 1-50	39·1	55·0	94·1
Ave. 1-100	19·5	43·0	62·5
Ave. 1-500	3·9	25·5	29·4

Note: Contractor furnished weight = 128,717 lb.

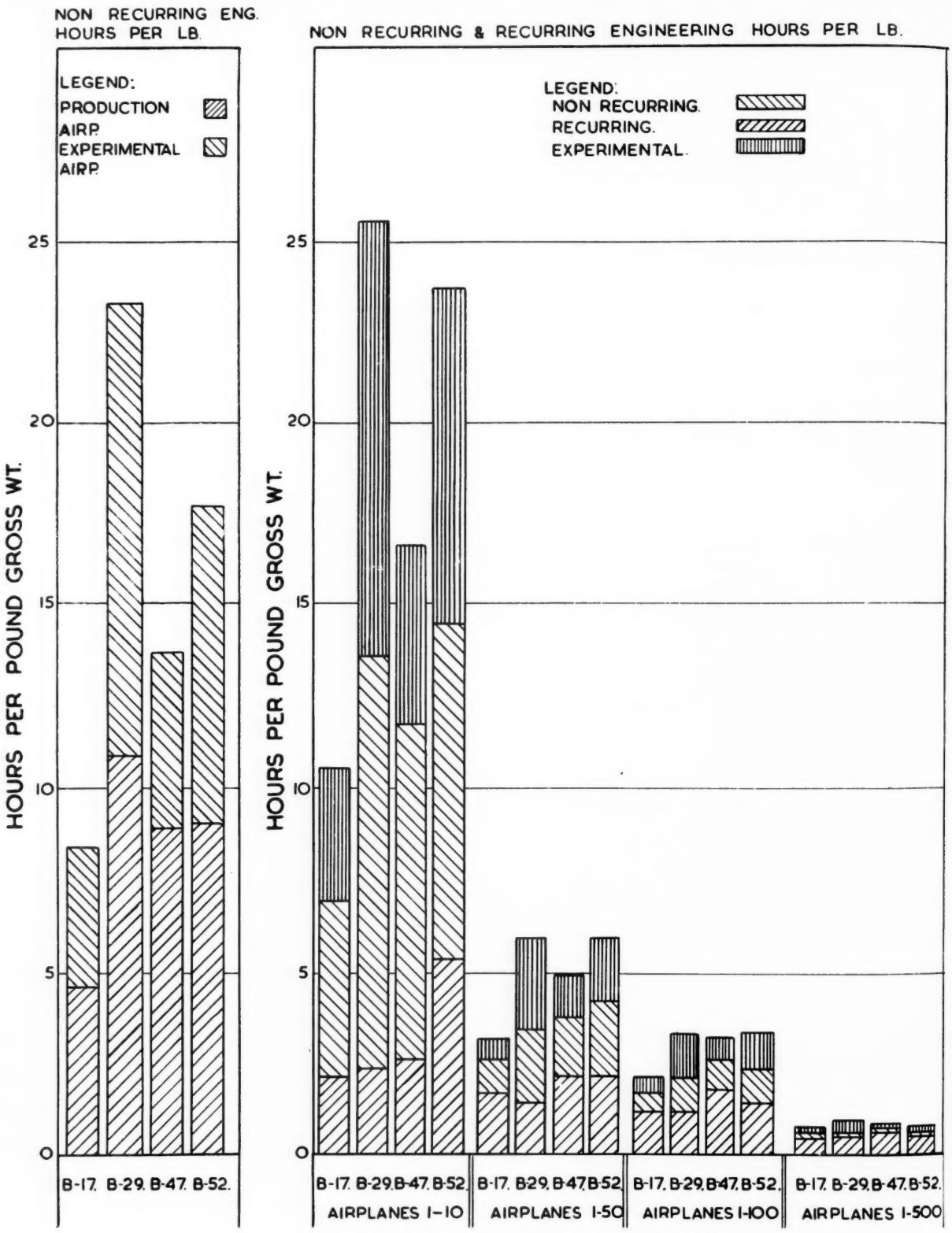

FIGURE 2. Bombers. Engineering hours per pound—gross weight basis.

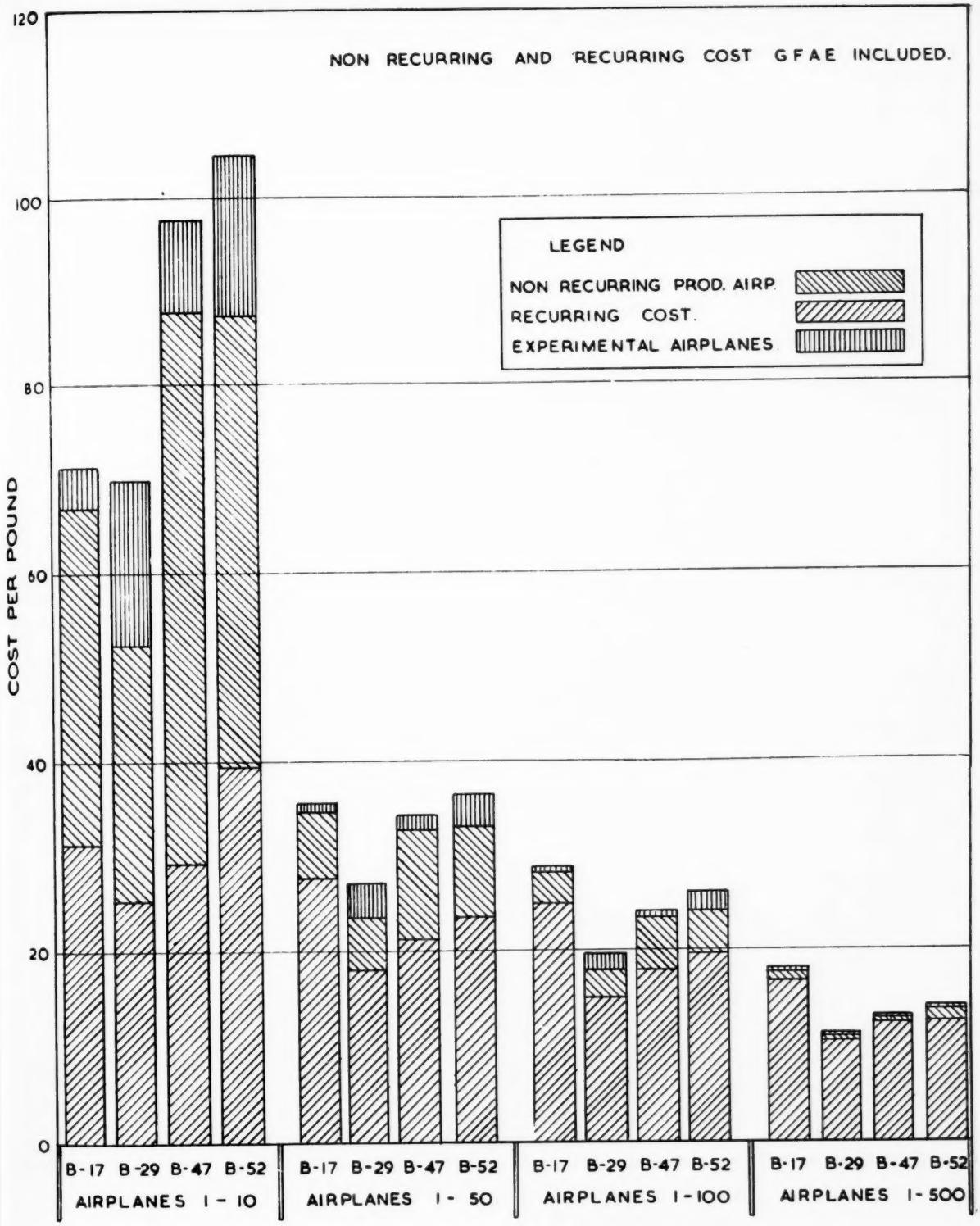

FIGURE 3. Bombers. Total cost per pound—gross weight basis. Indexed to 1952 prices.

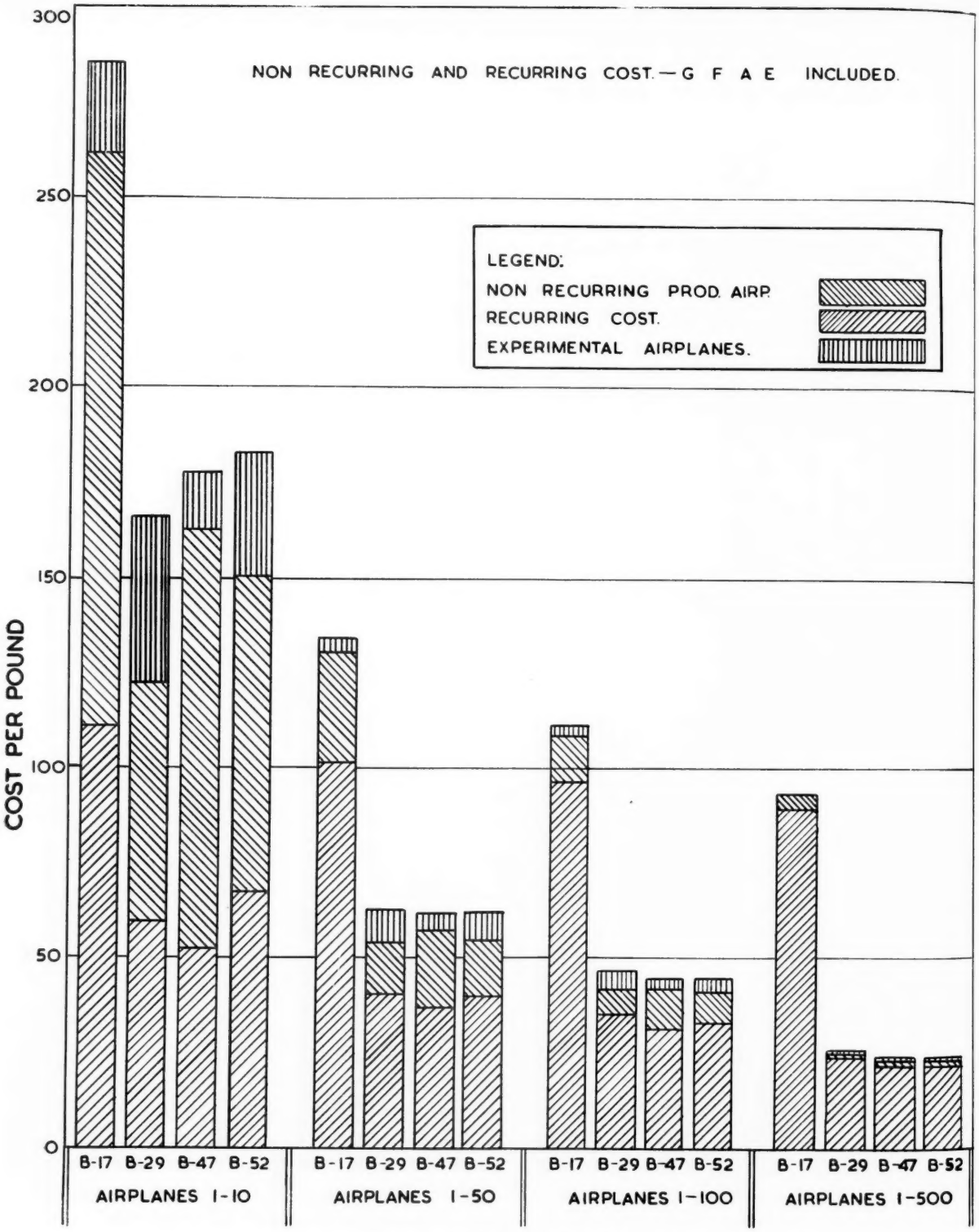

FIGURE 4. Bombers. Total cost per pound—useful load basis. Indexed to 1952 prices.

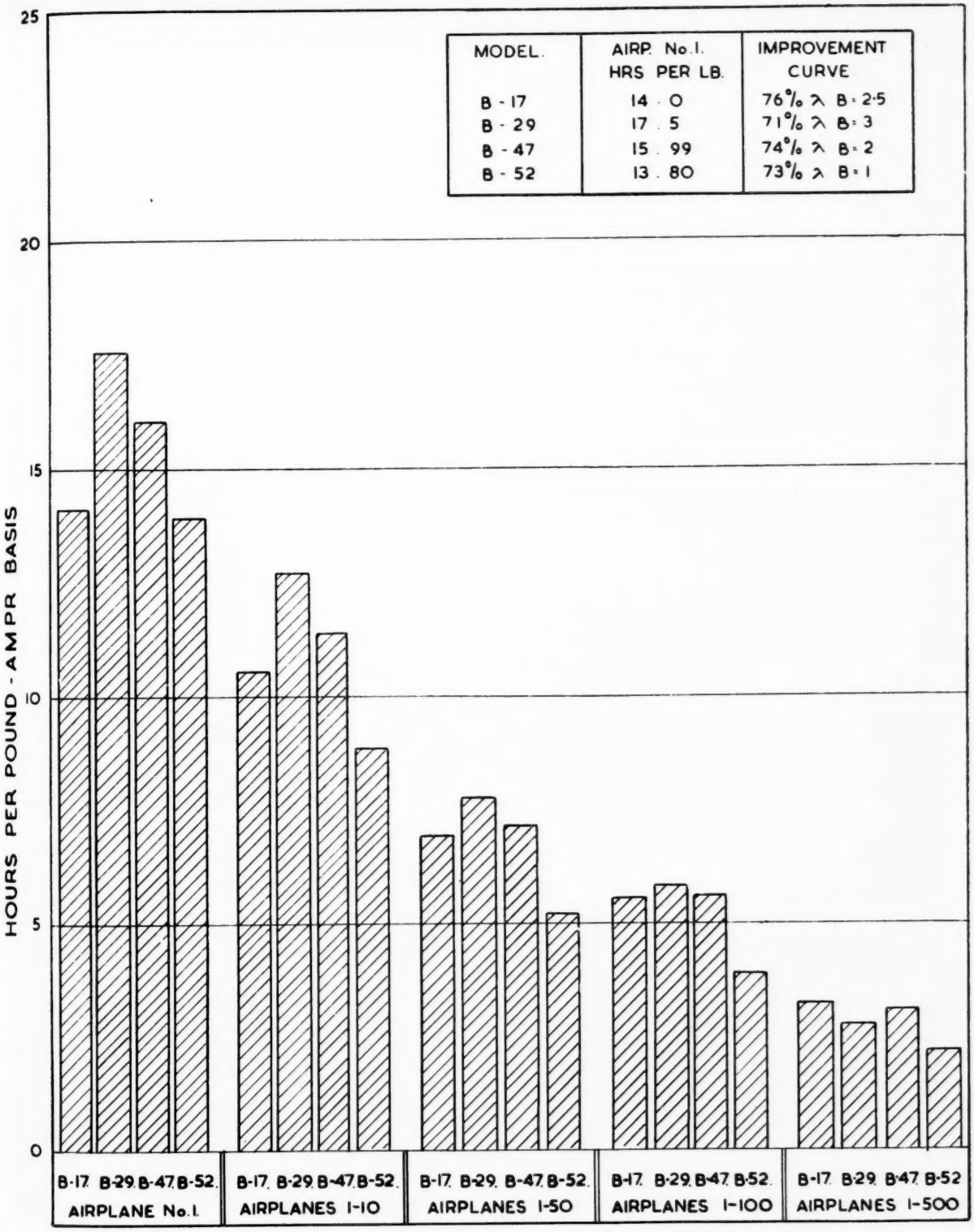

FIGURE 5. Cumulative production hours per A.M.P.R. pound. Inplant actual + vendor hours* = 100 per cent aeroplane.

*Adjusted where necessary to conform with Boeing history.

NOTE. { MODEL B.17 AND B. 47 TOTAL NON-RECURRING TOOL HRS. ALLOCATED TO No. 1 POSITION. MODEL B. 29 WICHITA MANUFACTURING.

LEGEND
- PRODUCTION
- RECURR. TOOL
- NON-RECURR. TOOL

MODELS		B 17	B 29	B 47	B 52
PRODUCTION LABOR	No.1. HRS. PER LB.	14·0	17·5	15·99	13·80
	IMPROVE CURVE	76%B25	71%B3	74%B2	73% B1
TOOL LABOR	NON-RECURR. TOOL No.1. H.R.S. PER POUND	63·70	159·81	151·03	124·72

RECURRING EVALUATED BY AIRPLANE QTY.

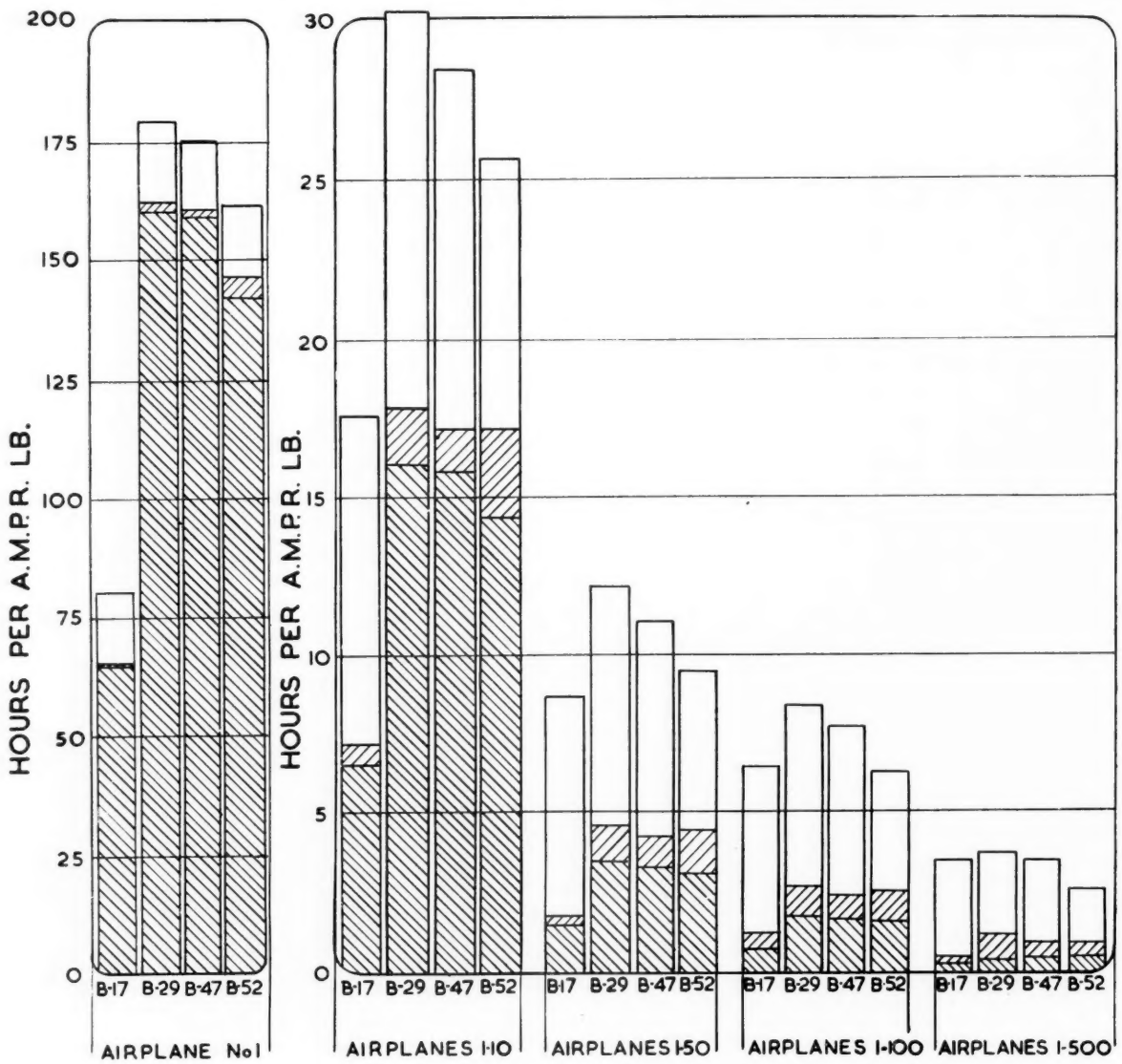

FIGURE 6. Cumulative tool and production hours per A.M.P.R. pound. Inplant actual + vendor hours* = 100 per cent aeroplane.

*Adjusted where necessary to conform with Boeing history.

DOLLARS PER POUND

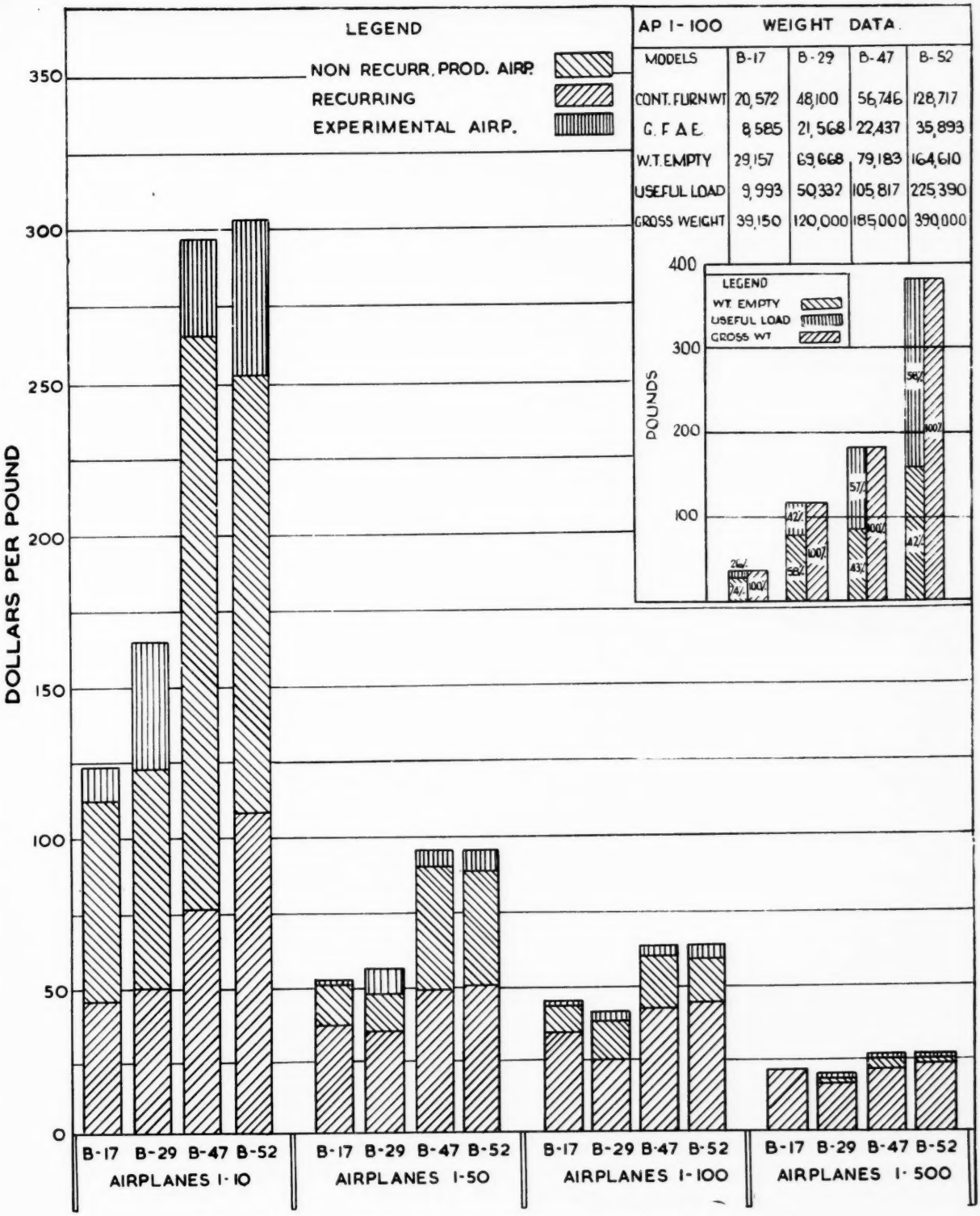

FIGURE 7. Total cost per pound—contractor furnished weight G.F.A.E. excluded. Indexed to 1952 prices.

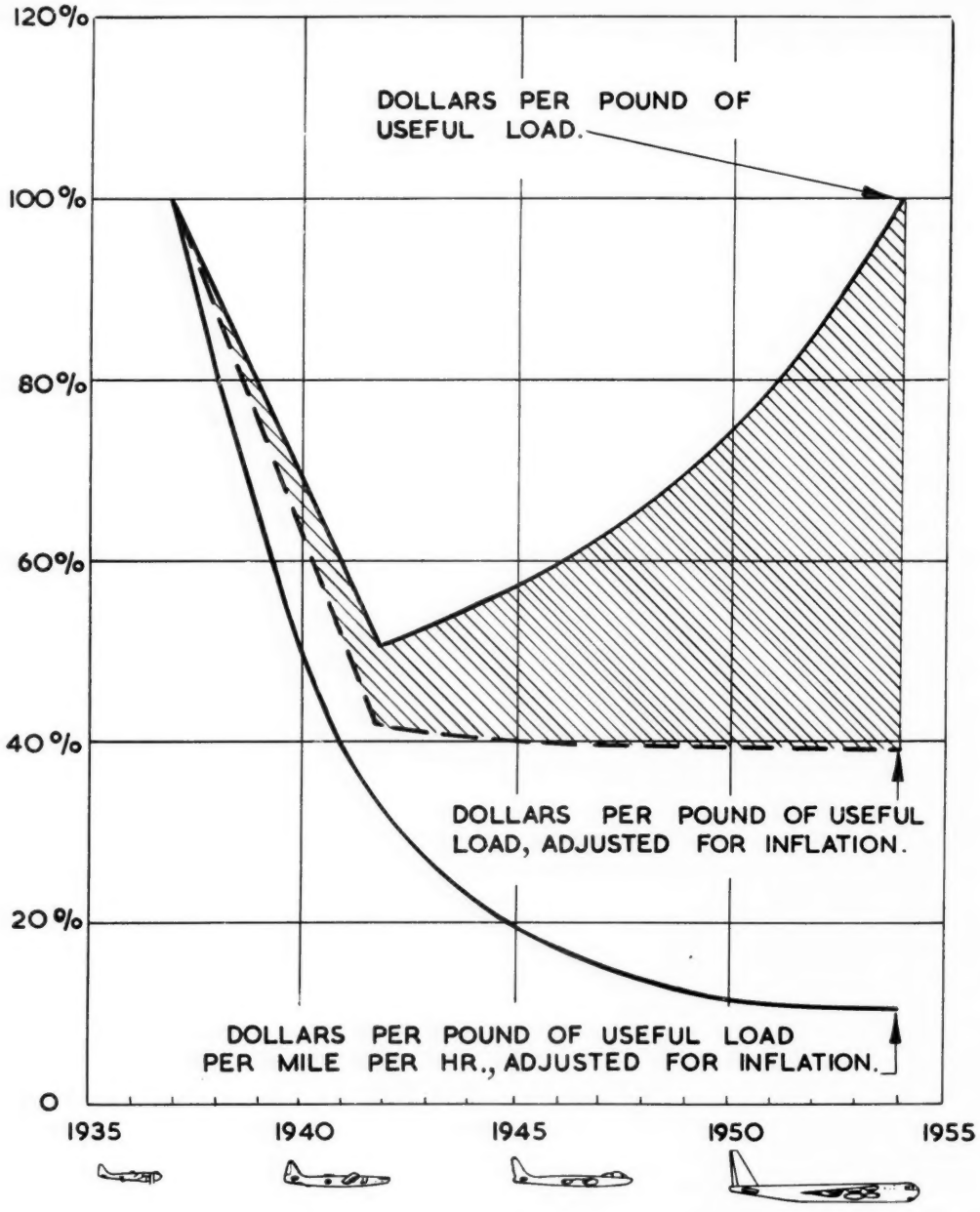

FIGURE 8. Per cent price change bombers. Aeroplanes 1-100. Includes: Cost of experimental models. All non-recurring cost in 1st position.

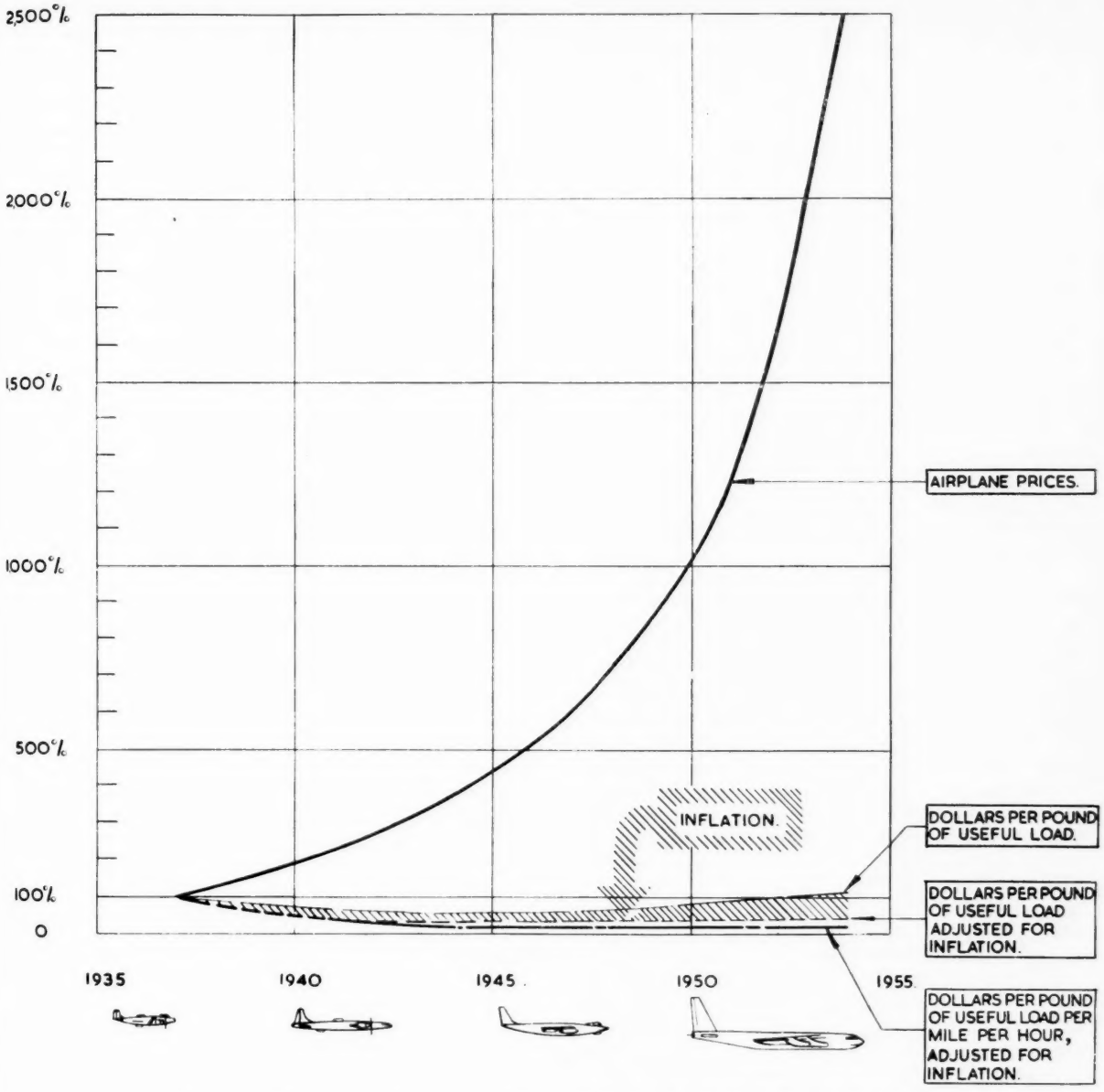

FIGURE 9. Per cent price change. Aeroplanes 1-100. Models B-17, B-29, B-47 and B-52. Includes: Cost of experimental models. All non-recurring cost in 1st position.

DISCUSSION

HANDEL DAVIES (Deputy Director-General of Future Systems, Ministry of Supply, *Fellow*): It had been a fashionable pastime for some years now to make pronouncements about what was wrong with British Aviation; and it had been noticeable that the loudest criticisms had usually been made by people who had not themselves been actively involved in the business of designing or making or flying or testing aircraft, or with any of the associated research and development activities. Tonight, however, they had been privileged to listen to someone who he thought could hardly be more qualified to pass judgment on this subject for he had been involved for many years on both sides of the fence, in industry and in the services. And although few of them would agree with all that Air Commodore Banks had said, he thought they should be grateful to him for having given this lecture in such a forthright and stimulating way. For there was one thing which they

in this country could afford less than anything and that was complacency.

Air Commodore Banks had been a little hard on them at the beginning of the lecture, and he would like here and now to say that he did not think the order of merit in which he had placed British equipment in relation to the equipment of other countries could be substantiated by the facts; nor did he think that he had been just in saying that "owing to indiscriminate ordering off the drawing board very little has reached the production stage." The fact that, at this moment, there were large numbers of Hunters in service in the Royal Air Force and the re-equipment of Bomber Command with the V-Bombers was well under way, belied such a statement. Nevertheless, he agreed wholeheartedly that they had not, during the past ten years, done as well as they might and that they must do a lot better during the next decade if they were not going to be left behind in the race.

On the main part of the paper there were two brief general comments that he would like to make; the first on the planning phase and the second on the design and construction phase. On the planning phase he was sure they would not expect him to make any detailed comment on the stimulating suggestion the lecturer had made about possible reorganisations in the government side of the business, but he would be bold enough to say this much in very general terms: if you want to do a planning job properly there were two conditions which must be fulfilled. First, the number of planners involved must be as small as possible and, secondly, the planners must know something about the things they were planning; that was, they must have been actively engaged in the business themselves. Neither of those two conditions were fulfilled by the present system. He felt very much in agreement with the suggestions the lecturer had made about the need to have a self-contained organisation within the Ministry of Supply to do their forward thinking. He also thought it would be a good thing if they could achieve the aim which he had mentioned in getting the operational requirements staff working under the same roof and even under the same Controller as the planning or technical staff, or whatever they were called; but whether anything even approximating to that could be achieved so long as they had two separate Ministries—the Air Ministry and the Ministry of Supply—was extremely doubtful.

Now with regard to the design and construction side: the lecturer had produced some extremely interesting data, particularly in Figure 1 and Appendix 1. If his arithmetic were correct, he believed the figures implied that the number of engineers involved in the design of the F.100 amounted on the average to about 500 spread over 4½ years and he would like to ask the lecturer if he could confirm that that represented the number engaged on the airframe side alone and did not include the equipment and engine design. If that were so it was rather a significant figure, because another very simple bit of arithmetic would then demonstrate that with the available technical and scientific manpower resources they had in this country they could only afford to have perhaps eight or nine design teams of that size, making due allowance for equipment and engine design. Now that was a conclusion which many people had reached without these figures in the past. It did underline the really important and fundamental difficulty against which they stood. He referred of course to the appalling shortage in technical and scientific manpower from which not only the Aviation Industry but the country as a whole suffered. Two important conclusions seemed to follow from this; one affecting industry and the other affecting the planners. The one affecting industry was that they really must achieve a greater measure of integration. He agreed entirely with Air Commodore Banks that there was no question of attempting to coerce the Industry into this, but it was perhaps not out of place to suggest that some of the groups that already existed could perhaps go a little farther than they had in integrating the separate design teams which they had within their own organisation. On the planning side he thought it would perhaps be better if attention could be turned a little more towards trying to devise the best way of deploying and utilising the limited technical and scientific manpower and other resources available in the country and a little away from the purely financial limitations which tended to dominate the picture at present, resulting in a constant threat of arbitrary cuts, which eventually caused loss of morale and efficiency.

AIR COMMODORE BANKS: Mr. Handel Davies was the living example of the point he had made in the lecture; and, at last, someone had been given the job of dealing with "future systems."

In reply to the query regarding the number of engineering personnel involved in the design of the F.100. He should think that this figure would be nearer 1,000. The engineering manhours given included some engineering items not strictly of a design nature but, just the same, they absorbed manpower. These non-design items were: aerodynamic studies, reports, reliability analyses, model design and construction, wind tunnel monitoring and data reduction, flight test instrumentation and maintenance of the aircraft during flight test, design and construction of test rigs for evaluation and qualification testing. The figures did not include the manpower engaged upon equipment or on engine design and development.

G. R. EDWARDS (Managing Director Vickers-Armstrongs (Aircraft) Ltd., President-Elect, Royal Aeronautical Society, *Fellow*): He would like to add his compliments to those of Mr. Handel Davies. This business about timing of aeroplanes of course had been spoken about with great enthusiasm by many much less qualified to do so than the lecturer.

Being constructive—too much time was lost before the job actually started. If the time it took somebody to start was so well spent that you could be assured when you had started that the purchaser was prepared to go through "hell and high water" to get it, then one would accept that time as well spent, highlighted by the good old-fashioned practice of starting something off with

fireworks at night and perhaps the inevitable cocktail party. But so often, something that was very difficult anyway began to look rather more difficult than the purchaser who started it thought it should be. The axe came out, and another great slice of this technical manpower, which they were so often told was in such short supply, was quite calmly thrown away. If they were going to save time and get things done more quickly, then they ought to accelerate the time it took to start; and having decided they were going to start, make quite certain that they were not going to stop.

One big reason why technical manpower was short was because they dissipated much of it. Let them use it to better advantage than they used it at the moment.

The lecturer mentioned Russia in his paper. He would have thought that Russia was a powerful addition to the competition they would have to face so far as civil aeroplanes were concerned. A pretty powerful addition at that. It was a sobering thought that the only civil jet aeroplane in scheduled service at the present time was a Russian one. Within a matter of months they would probably be flying a couple of civil propeller-turbine aeroplanes in the Vanguard/Electra class. If they had one thing in common with the Americans it was that, despite the great resources which they both had, they took good care not to waste them, either by light-hearted starts not to be finished, or by unnecessary triplication—particularly of Bombers.

He thought that the civil aircraft business was the Industry's affair. He did not see why the Industry should look to the Ministry of Supply or any other Ministry to tell them what civil aeroplanes to build, how fast to make them, or to whom to sell. If the Industry individually were not strong enough to face up to the consequences of going into the civil market, then individually it should stay out of it. He did not see why it should expect to be financed by the Government. He had an unswerving belief in the value of direct maker-to-user in this business confirmed by his experience with B.E.A. and other civil airlines. For military aircraft, too, he thought maker-to-user had much to be said for it and could make a major contribution towards the production of better aircraft, sooner.

He hoped, Mr. Lecturer, that if in five years time someone read a similar paper he would make as good a job of it, but would not have the same thing to grumble about. Progress over the past five years did not, however, encourage one to believe that it would be so.

AIR COMMODORE BANKS: He was most grateful for Mr. Edwards's remarks since he, probably more so than any of them there, had had greater experience in both the military and civil fields since the War.

The only remarks he had made which might be the subject of argument were those regarding civil aircraft. He did not quite agree that there should be no Government financial support for such aircraft, but was fully in agreement with direct contact between the manufacturer and operator. He could not see how they in this Country could expect to get a start in civil aviation without Government sponsorship—certainly for such expensive items as the engine. In the case of large aircraft, of 200,000 lb. a.u.w. and upwards, Government help would surely have to be forthcoming for the airframe alone, if not for the engine—which latter might already exist in military form.

S. SCOTT-HALL (Scientific Adviser to the Air Ministry, *Fellow*): He would like to pick up the thread of his remarks from the first paragraph of the lecturer's conclusions, where he pointed out that anybody who had had the advantage of being abroad and seeing what was done in other countries had got a perspective which helped a great deal in looking at these problems. He was sure the lecturer was right and, in his own case, three years in the United States certainly did not induce in him any sense of complacency. At the same time he thought that great caution was needed in applying the experience that one gained in the United States and what one saw going on there, to the situation here. Quite apart from a vast disparity in resources there were, in his opinion, even more fundamental differences than this. There was a difference of outlook and a difference of temperament.

It seemed to him that there were two things which were quite clearly wanted. First of all they must have a proper appraisal of what they wanted in new weapons and a proper appraisal of the time at which they wanted them. Never before in the history of aeronautics had these decisions been so difficult. Never had there been so many alternatives and never had they been so expensive. Although at the present time it was much easier for the United States, with the money and the resources at her disposal, to have virtually everything she wanted, than it was for Great Britain, he suggested that possibly even in the U.S.A. the time was coming when it would have to be one *or* the other and not both, and such decisions were extraordinarily hard.

As to *when* they wanted their weapons, it seemed to him that timing did not necessarily mean haste. To wait and see might be a good policy if you were really uncertain what you wanted to have ten years hence. He would also point out that the history of this country showed instances in which this policy had paid off remarkably well. As to the value of time, well, it was incontrovertible. If you had decided when you wanted a thing then obviously you must get it when you wanted it and not three years later. And here he thought there was a lesson which could quite clearly be learnt from the United States, and this again he thought the lecturer had stressed. He did not believe from his experience on the other side of the Atlantic that they had properly estimated in this Country the effort in engineering manpower and experimental resources required to carry out what they had attempted. One particular deficiency which they had suffered from was the lack of wind tunnels. When one saw the amount of wind tunnelling that was done on the average American design, compared with their own, one was struck with some dismay.

The lecturer referred in his paper to the private venture. Well, they all knew that the private venture was an extraordinarily valuable device in the past. He had

one suggestion here drawn from present American practice. The Air Research and Development Command of the United States Air Force, who managed these matters, had regular meetings with American aircraft manufacturers at which they discussed what they called their "systems requirements." Now the "systems requirement" appeared a considerable time before the final detailed requirement was drawn up, and this practice did, in fact, give the manufacturer's designer the opportunity to start planning a design much sooner.

The Americans, once they started on any job, did not waste any time and their energy and the intensity with which they worked was a never-ending source of astonishment to him.

AIR COMMODORE BANKS: He quite agreed with Mr. Scott-Hall's remarks regarding the experience gained in other countries and its sensible application to their own needs. While one could not slavishly copy America, since her production and production outlets were enormously greater, there was a good deal that one could learn from the meticulous preparatory work which went on there in the design and evolutionary stages of an aircraft. He was also aware that the Americans had had their failures in both aircraft and engines; but they were in the position to afford such failures whereas we were not, and with our more limited effort it was all the more necessary to avoid the chance of failure—by speedy and accurate formulation of a requirement and the maximum possible test facilities to aid the design teams in achieving success.

He would say, here and now, that our aero-engine industry, particularly, had in the overall shown itself to be capable of designing, developing and bringing to fruition a greater variety of superior gas turbines than could be seen or had anywhere else in the World.

He did not quite agree with Mr. Scott-Hall when he suggested that, "wait and see might be a good policy." Time and timing did not mean haste, and the speedy formulation of an operational requirement, together with a sound technical policy, avoided delayed and delaying action and ensured expeditious handling of all that went to get an aircraft into service. He could assure him that this type of procedure operated very well when the incentive was purely commercial! He thanked Mr. Scott-Hall for his other valuable points.

M. N. GOLOVINE (Director, A.T.S. Company, *Associate Fellow*): There was little he could add to Air Commodore Banks' clear and concise review of Weapon System genetics.

He could not help feeling that it would be extremely difficult—if not altogether impossible—to cut total times by nearly a half, unless the process of initial assessment and evolution of projects were greatly speeded up and results made more reliable.

In view of the complication of modern Weapon Systems he suggested that two distinct phases should be considered, namely:

1. Evaluation of requirements and projects; and
2. Co-ordination of design, development and production of complete Weapon Systems.

Since these two processes were distinct in the time and type of work involved, it seemed preferable to split the responsibilities between two separate organisations. Major Evaluations should be done by a virtually independent body such as Rand, while co-ordination of advanced or complicated Weapon Systems could take the form of project management—for example, Ramo-Wooldridge and the Convair SM-65 "Atlas" Intercontinental Ballistic Missile.

His personal opinion was that Government Departments and/or official research establishments were not necessarily ideally placed or even equipped to deal with these two problems. In both cases it might be advisable to have independent, specialised bodies—*not Committees*—with no particular technical or industrial doctrines. Moreover, certain types of Evaluation would require a very wide approach to the particular problem under consideration, involving a detailed study of political, strategic, tactical, industrial, economic and even physiological and psychological factors. Some might feel inclined to add psychiatry!

The necessity for such new techniques was becoming evident in the case of more advanced projects calling for the close collaboration of a number of specialists. Good examples were satelloid or satellite developments such as "Vanguard." A corollary would be the elimination of artificial distinctions between aircraft and so-called Guided Weapons.

He fully agreed that the original requirements should be very simple, to be developed by whole-time Evaluation teams. If the work were properly done a drastic selection of acceptable solutions in the pre-project stage would help to eliminate a number of unnecessary and defective designs and potential prototypes. Only then would it be possible to go back to simple, straightforward tendering by constructors.

As pointed out by the lecturer, "hunches" and "guesses" were now out of date. In the final analysis a great deal of time and money could be saved by using adequate tools—wind tunnels, computers and simulators.

Time and timing were equally important in Civil Aviation. While some of the technical problems were simplified by the absence of armament, the commercial aspects—namely market research and analysis—brought in a number of additional unknowns. In other words, sales methods would have to be revised and put on a more scientific basis.

He suggested that they were moving into an era where mathematical methods would assume an ever-increasing importance. This was clearly demonstrated by tendencies such as the application of the theory of probabilities to many military problems.

Consequently there was nothing fundamentally unsound in the hypothesis that at some future date even Civil Transport market computations would involve the use of techniques adapted from von Neumann's Theory of Games and Statistical Decisions.

AIR COMMODORE BANKS: He was very pleased to have Mr. Golovine's remarks since he was sure that, if they were to progress, there would have to be a more mathematical treatment of the aircraft's role (military

and civil) when formulating a requirement and issuing a specification. That was where he thought they could, with benefit, learn from America, even if they could not embrace completely their elaboration.

DR. CAWOOD (Ministry of Supply, *Associate Fellow*): Possibly they would think he ought to begin by springing to the defence of the organisation of the Ministry of Supply; but he was not going to do so. First of all he knew far better than to take on a poacher turned gamekeeper. Also, he did not know much about administration. He personally had never found that it mattered very much. He had worked in the Air Ministry, in the Ministry of Aircraft Production and he had been devoured by the Ministry of Supply; and it was his experience that once you became familiar with the new machine and were prepared to play it, it really did not make a great deal of difference; so he thought that Air Commodore Banks had described a problem which was far too fundamental to be solved by changes in administration. The plain fact was that the modern aircraft was a very complicated set of mechanisms and so on, and the number of manhours required to develop it and then produce it were extremely high. He thought the lecturer's figures from America showed that. He did not think there was any great difference in the total manhours required in this Country or in America. They had greater resources there and, therefore, they could increase their labour force and cut down the total time. Now he did not think this was too practicable in this Country. It was a smaller country and he did not think that was the way they ought to tackle it.

What then were the alternatives? They could accept this long development period, getting on for ten years for a major project. Well, he did agree with the lecturer that they should not. In a dynamic field of engineering and science, like aeronautics, advances took place almost from day to day, week to week and if they took so long before they saw the fruits of these advances then aeroplanes were likely to be obsolescent before they got into service. He did not think they ought to sit down and accept the fact that it took this long period. They could of course cut down the number of projects in order to accelerate the few, and there was no doubt they would have to do this to a certain extent but he did not think that this either was very satisfactory. So he thought they had got to look at the actual aircraft themselves. Had they become too complicated? Had they become too sophisticated—and here it was worth while looking at the Russian aircraft because they were going to have to meet competition, he was quite certain, in the near future from the Russians; and the Russians claimed, and he thought with fair justification, that they had developed and put into production and service some of their major projects, four-engined, civil and bomber aircraft, within five years and he did not think that was too far wrong. How had they done it? Their organisation was a little different from ours but there were other differences on this question of design. He believed their steps in development seemed to be rather shorter. Their whole approach, he believed, was simpler and more direct. They did not go in for insurances or frills. They appeared to use far fewer alloys, special alloys and materials. They relied far more on welding and fabrication of parts than on forging and machining and, finally, he thought they relied far more upon an enormous labour force. There was nothing we could do about the latter.

He thought there was no doubt that this approach of the Russians led to a rather lower quality product. They felt, during their recent visit to Moscow, that, for instance, their structure weights were probably a little up on ours and the specific consumptions of their engines were rather higher and so on. But if at the end of five years the aircraft was in service, and they had no fatigue troubles and their maintenance difficulties were few, who was to say their outlook was wrong?

So he did think that they had to review their own projects to see if all this complication and sophistication were thoroughly justified even in the highly competitive civil market. Possibly their engineers were too much attracted by the scientists' promises of the future!

Now Air Commodore Banks referred to those fashionable words the "systems" concept and in the Ministry of Supply they were very sympathetic to this idea and were very lucky to have Mr. Handel Davies to start this new project with them; but he did not know that that was going to have the effect of cutting down development times—indeed, there were dangers the other way. They must remember that the background of systems' philosophy was the realisation of a very precisely defined task or operation which required every component of the system to be stretched to the limit if the task were to be undertaken efficiently or even practicably, and the final project therefore was of itself very highly specialised. If they allowed this sort of philosophy to run wild, each new aircraft would have all its own special equipment, different voltages and frequencies in its service supplies, different hydraulic pressures, special flight instruments and so on; and this would obviously take far more manhours and the development time would be longer. It might easily be doubled. The problems of maintenance and, of course, the provision of spares could be quite overwhelming to any Air Force or civil airline. So they must approach this business with great caution. He thought there must be some thread of co-ordination and standardisation of components and so on, underlying all these studies and he believed this would be one of the important tasks of the Ministry of Supply in the future.

Just one final point on the Russian organisation. Surprisingly enough it was extremely like their own. They had the equivalent of the R.A.E. and, also, N.G.T.E.; they had a Boscombe Down and so on, all within the Ministry of Aviation Industry, and they had test airfields run by the Russian Air Force for the Service acceptance tests. The biggest surprise, making allowances for the fact that the whole thing was State-run was that they managed to remain quite competitive as between designers. But he thought the most important difference was this: that when a new operational requirement was tabled, in the early days, it went to and fro between the Service and the Russian Ministry

of Aviation Industry, at the lower levels, the assessment levels, in much the same way as it did in this Country. When, finally, the Air Force decided "This is what we want," it then became a political decision. It went up to the Praesidium, that was to say, the Cabinet and the Cabinet then took a decision to go ahead or not, as the case might be, and at the same time laid down a dated programme. After that the Ministry of Aviation Industry got on with the job, and the most important thing was to meet that time; and if it were not met, he suspected the consequences were dire!

AIR COMMODORE BANKS: Dr. Cawood had said that he personally did not find that administration mattered very much! He thought it did, but it obviously depended upon those individuals who had the direct administrative responsibility; and his experience was that their influence could be very great indeed.

While he agreed with Dr. Cawood that the greater resources of America, and presumably Russia, permitted those Countries to increase personnel to meet an increasing manhours' requirement and so to reduce elapsed time, the very fact that in this country they could not be so liberal was one of the points of his lecture. Therefore, they must reduce the number of projects and avoid indulging themselves in having a large number of baskets for their eggs. Successful British firms had already found it necessary to increase largely their design and technical staffs, and the equipment needed for the development of the more comprehensive and complicated systems of the modern aircraft.

Despite the implied criticisms in his lecture, he did not advocate a violent and devastating rehash of the departments dealing with procurement; but had asked for a regrouping into more cohesive sections of those directly concerned with procurement in the Air Ministry and Ministry of Supply. With this regrouping, there must be a different outlook. At the moment, they appeared to have altered their methods very little from those existing before the War, whereas the complexity of the modern aircraft had increased many hundred times since then. One thing was certain, whether they liked it or not: there would be no decrease in the overall complexity of the modern military aircraft. But there could be some degree of co-ordination, if not complete standardisation, in the type of systems (electrics and hydraulics, etc.) used in the various types of aircraft, and he agreed that the Ministry could be of very great help there.

While a simple fighter with the minimum of elaboration in its equipment was a laudable objective, it might have little chance against an adversary of similar performance having a more sophisticated and better developed means of sighting and hitting the target. And they had, as yet, no knowledge of the serviceability of Russian aircraft, or whether or not they suffered from fatigue troubles. He would bet they did—just like any others!

R. L. LICKLEY (Chief Engineer, Fairey Aviation Co. Ltd., *Fellow*): The essence of the paper as Air Commodore Banks had put it was time, and he made the suggestion that times could be halved. If they were to do that they must consider the whole process from the very start. He would like to endorse what some earlier speakers had said namely, that delays at the start could magnify throughout the whole programme. In his conclusions, the lecturer suggested, and he would like to support him very firmly on this, that a stable Government policy which would see an agreed programme through to fruition without frequent financial hindrance, was required.

Mr. Edwards pointed out the problem of the axe which hung over them and fell every so often; but a lesser-known action which was even more damning in certain instances was the slowing down, the "don't spend so much money this year, but you might get it to spend next year." That was an even greater delay, he thought on some programmes, because at least when a thing had been stopped you knew that you did not have to spend the effort.

No one so far had dealt with the effect these matters had on staffs. Some speakers had suggested that there were not enough technical people. Mr. Edwards said, and he agreed with him, that there were enough if they were properly used. But they were all going elsewhere because they saw other industries where there was a planned future, or they thought there was a planned future, in which straightforward statements were made on the policy, particularly in the case of atomic energy, which would be followed ten years hence. The Aircraft Industry operated in violent fluctuations, which meant that good staff and very often the best staff wished to leave it. That had an immediate result and an immediate delay on any programme; and one of the most frustrating things was when a team had built up to a very high standard of enthusiasm to submit a project, and they were all ready to go and get ahead with that project, the discussions as to whether it should go ahead or not went on for so long that the people became frustrated, decided it could not take place and left the firm. The elimination of this type of delay was one of the major things which could cut down the time factor.

Facilities came in a secondary position to this and it was important to remember, as Air Commodore Banks said, that there was no backlog of orders if you were in the military business. You might find yourselves committed to very large facilities and overnight they were of no use to you, because the work was cancelled—and a firm must take account of that in any of its planning. If there were a clear indication, as had been suggested, that once the job was started you went through to the end, then much greater facilities could be made available and used.

The suggestion that outsiders might operate as planners seemed to him a bad one, particularly in this Country. If they were dependent upon Government aid, then it seemed certain that there must be a Government planning staff and all he would do was endorse earlier speakers' views that it should be first class. The outsider suggestion, on the lines of some of those American corporations, would be groups of people without responsibility but still making decisions, and he thought that all would suffer from that effect.

Mr. Scott-Hall mentioned "waiting and seeing,"

which might sometimes be good policy. From the Aircraft Industry side, they had been waiting a long time, but had not been granted the vision afterwards!

AIR COMMODORE BANKS: He thought Mr. Lickley had put his finger on a very important point when he mentioned the slowing down process, *i.e.* "don't spend so much money this year, but you might get it to spend next year." This inevitably put a brake on effort and caused serious delays; and he agreed that its effect on staffs was equally bad. The "violent fluctuations" of the Aircraft Industry, which Mr. Lickley mentioned, must have been the cause of many valuable technicians forsaking the Industry and going to others showing greater stability. It had been one of his purposes in giving this lecture to plead for more stability in the Aircraft Industry, by the proper programming and continued support for their military and civil needs. For instance, he did not think it feasible to consider a yearly budget, reviewed almost continuously throughout the year from the financial angle, when the period of gestation for an aircraft was between five and seven years. There should be a five- or seven-year plan for the Industry, reviewed yearly and adjusted accordingly.

He did not mean to suggest that outsiders might operate as planners but rather, if there were a shortage of such individuals, the posts in a Ministry of Aviation should be sufficiently remunerative to entice people with administrative and planning experience from industry, wholetime—and he did not necessarily mean from the Aircraft Industry. There were sufficient people of technical ability in the Ministries concerned to deal with their opposite numbers in the Industry, but a few top administrators might, after a year or so, better co-ordinate and control the total effort.

Both Mr. Lickley and Mr. George Edwards had said, or inferred, that there were adequate numbers of technicians available, and it was their proper or improper employment which made for an apparent sufficiency or shortage. In this connection, the figures given below might be of some interest.

No. of qualified engineers graduated per annum per million of population—in 1955.

U.K.	56
U.S.S.R.	300
*U.S.A.	137

*In 1950, the specific figure was 312 for the U.S.A. The cause of the large reduction of trained engineers in 4-5 years was not readily explainable.

B. S. SHENSTONE (Chief Engineer, B.E.A., *Fellow*), *Read by R. H. Whitley*: It might be of interest in connection with Air Commodore Banks' remarks on direct procurement between national airlines and the Aircraft Industry, that B.E.A. had had experience of procurement through the Ministry of Supply and direct procurement. Experience from B.E.A.'s point of view showed that it was far more desirable to have direct procurement between operator and manufacturer. That was not to say that the Ministry of Supply were in any way obstructionist, but extra links in this sort of chain should be avoided because they were all conducive to delay and argument.

Although it was perfectly clear that, from the military point of view, the widespread use of sub-contract work both for parts of the design and for manufacture was the right thing, it was not necessarily the right thing for civil transports. The life of the civil transport was so much longer than that of any military aircraft that much greater consistency in its parts was required. If different parts were designed and built by different groups, it was almost impossible to ensure the same standards of life. On the other hand, such sub-contracting was done very widely both in the U.S.A. and in the U.K. and it might have to continue but, from an airline point of view, it was not desirable.

Air Commodore Banks had mentioned the vast amount of development and manhours that must go into a first-line civil transport. This clearly pointed to the necessity for there not being too many manufacturers in this field, for otherwise the work would be spread too thinly for them to break even or for them to produce a product of sufficiently high quality. In the U.S.A. there were only four firms seriously in the first-line transport market—Boeing, Convair, Douglas and Lockheed. In all of these, transports were not by any means the main source of livelihood. In the U.K. there were three firms in this big business:—Bristol, de Havilland and Vickers. Some people had said, considering the market and considering the number of British Airlines, three were too many. If they realised that there were only about half a dozen airlines in the whole world capable of introducing a new first-line aircraft for the first time, and that there were seven manufacturers chasing after them, it ought not to be too difficult to work out whether there were enough airlines in this category, or too many manufacturers. New civil transport aircraft were going to be more difficult to design and they would be designed and built under more severe competitive conditions than in the past.

Even nationalised airlines must get what was promised at the time it was promised. Too late was as bad as no good. In dealing with Air Forces there were times when it was possible to accept the second best, and one felt that at times there was a certain degree of benevolence shown towards manufacturers who had not quite come up to scratch, but there was no cushion of this nature for manufacturers so far as civil airlines were concerned. Airlines served the public direct and the public had no benevolence, no pity and no money to spare for the substandard.

AIR COMMODORE BANKS: He agreed with practically everything Mr. Shenstone said, with the possible exception of his remarks on the disadvantages of the widespread use of sub-contracting. While interchangeability was vital, particularly in the case of civil aircraft, which went to a greater age than military machines, he saw no difficulty in ensuring similar life standards for the various parts if the sub-contracting were properly and rigidly controlled. Very few aircraft manufacturers could meet the inevitable fluctuation of work and face the ups and downs in manpower if they did not sub-contract when the going was good and production at peak.

He would not necessarily agree that three major civil aircraft manufacturers were too many for this

Country; but they should obviously concentrate on somewhat different types, so that there was a chance of meeting the various airline requirements without engaging themselves in uneconomic competition. And it must be appreciated that the problem of getting dollars helped to keep the Industry going, although it would have to be very active if it were to continue to live against the increasingly heavy American competition; and it should strike out in those particular types and sizes not covered by the U.S.A.

R. H. WHITLEY: Air Commodore Banks had outlined the system of assessing firms' project designs submitted to a requirement. He had emphasised the importance of increasing the prestige and facilities available to those M.o.S. branches who at present filled this function. His remarks were confined to the stage when the manufacturer had submitted design proposals. Prior to this he had suggested the provision of an overall requirement which in his example might be couched in the lines "to evolve a complete weapons system to intercept and destroy at, say, 50 miles from shore, an attacker flying at a Mach number of two at 75,000 ft." While he would entirely agree that it was the designer's business how he achieved a given requirement, it seemed to him that a requirement phrased in purely operational terms left too much unsaid and assumed too much knowledge of operational matters on the part of the aircraft manufacturer and could mean a designer assuming certain things which were not justified. Perhaps more important, how would the figures "Mach number 2 at 75,000 ft." be arrived at? If on the hunches of individuals this could be as dangerous as when such hunches were employed as between alternative designs offered to a given requirement. For example, if the attacker appeared at a Mach number of 3 at 100,000 ft. the defender designed to this requirement would be ineffectual. On the other hand if it appeared with a Mach number of 1·5 at 50,000 ft. the defender would have a better than necessary performance and could therefore have been available more cheaply and in larger numbers.

The point he was trying to make was that, prior to the provision of the requirement, an extensive survey of the operational proposals both from the attack and defence standpoint should be made, starting from project studies of aircraft embodying anticipated technical developments. Against such a background individual intuitions could function more safely, cross-checked but not inhibited.

He suggested that such a process, if it were not already in being, was the first step in the ordering process and not the assessment of the manufacturers' projects.

For civil aircraft, the position was rather different. All but a few operators had to accept aircraft off the shelf, that was, as designed by manufacturers for the market surveys which depended upon the intuitions of individual operators. For a few operators however, the opportunity existed to specify the aircraft which they considered fitted their particular operating and commercial problems. Here the problem became one of weighing up the demands of the operating and commercial sides of the business and setting them against what was possible in terms of available power plants. However, the manufacturer must look to wider markets than those offered by one operator so that the requirements must be able to meet a popular need, as assessed by the manufacturer, for it to be built at all.

AIR COMMODORE BANKS: An operational requirement was a need, a need stated in as precise terms as possible for an aircraft for a specific job. This need was based upon Air Staff knowledge of what the potential enemy had up his sleeve and also on the state of scientific and technical art in the Industry, which had to meet the requirement. Since it was bad and dangerous policy to under-estimate the potential enemy, the object was, so far as possible, to meet or exceed the need by a reasonable margin; and because the Industry had, or should have, the necessary technical availability or strength, he had merely suggested that they equip themselves with such personnel capable of understanding the full military significance of a requirement. There would still be Air Staff views and those of the Ministry of Supply on the shape and performance of the actual vehicle needed to meet the requirement, as in the past.

The examples given by Mr. Whitley of "an attacker at $M=3$ at 100,000 ft." or one coming in at "1·5 at 50,000 ft.," did not in any way alter the problem which had always faced an Air Staff, *i.e.* what had the enemy got, and would they have guessed right in their requirement to meet and deal with the threat.

S. BENTALL (Ministry of Supply, *Associate Fellow*): Air Commodore Banks referred to the assessment teams dealing with tender design and project analyses and to the statistical and planning department which existed in the M.A.P. days. It might be worth while pointing out that very detailed production evaluations of tender designs were made by a team which reported to D.G.A.P., dealing with materials' availability, production capacity, plant availability, relative ease of production and times scales. Also, extensive statistical production records were being maintained by a planning staff, particularly a comprehensive set of labour data. Discussions with the firms in the Aircraft Industry on production planning topics, especially manhours and learning curves, were made difficult because of the frequent apparent lack of basic planning information at the firms and their reluctance to release any information which could be quoted against them, for obvious reasons. Symbolic of this attitude was the fact that Air Commodore Banks had made reference solely to American data in Appendices I and II. How refreshing would it have been to have some comparable British figures from the lecturer's Company.

His general impressions, partly gained from a visit to the U.S.A. last year, were that there was astonishingly little difference in the production cycles, times required to achieve peak production rates, direct to indirect labour ratios, labour to floor space density ratios and, a comparison of individual plants of comparable size and output rates on both sides of the Atlantic was not unfavourable to the British counterpart. This was

quite important, because if one looked at Lockheeds and compared the Hall of Giants with a very much smaller British firm, obviously the comparison was unfair; but if you took firms of comparable labour force and floor space size you found that, assuming they had similar production quantities, the manhour per lb. rates were extremely close and there was remarkably little difference in these figures. Not only that, but even the manhours for the first production or preproduction batch aircraft, for what the Americans called the "A" value, there was a close affinity. The figures for American fighters and bombers were almost identical with their British figures for the present generation of aircraft. The possible comment one could make was that the Americans were just one jump ahead in their generation of aircraft and they were being compared with slightly obsolescent British Aircraft. But just taking these figures by their face value as they were today, they were interesting and certainly revealing.

AIR COMMODORE BANKS: He could say "touché" but he was not going to because he had said in his lecture that, given the production orders, British aircraft and engine production would be as good as any in the World. In fact, it was quite as efficient as American production in the last War. His criticisms had not concerned the pure production of aircraft but rather of the time it took to get an aircraft to the production stage. At the same time it was true to say that America, because of the large numbers she produced, could buy and use expensive machine tools which made better structures, although it was not always necessary to have sheer numbers to put in some of this equipment. For instance, Dassault of France were using very novel production methods for their Etendard fighter. This had a 45° swept-back wing of 6 per cent chord thickness. The wing was milled in two halves on a Giddings-Lewis miller, and the fuel tanks were milled as integral parts of the wing. The correct wing contour of each half was obtained by heating it in an oven at about 135°C for one or two hours. Final contouring was done in a press. An Anderson machine was used for the forming and correct contouring of the fuselage skin. This process took a fraction of the time of the older methods.

DR. G. S. HISLOP (Fairey Aviation Co., *Fellow*): He had two questions to ask. At the outset Air Commodore Banks made a statement which was picked up by Mr. Handel Davies about the relative placing of the British Aircraft Industry quality in respect to Russia, America and Sweden. Thereafter, in the lecture, the lecturer concentrated primarily on the American scene. Could he give some explanation, based on figures of engineering manhours required to produce production aircraft for the Swedish industry? Sweden was a country with, he thought, a population of the order of 7 or 8 million and yet had apparently, according to the Air Commodore, produced better aircraft (he presumed fighters) in a time scale which was more in accord with the American record than that of the U.K. Some analysis of this feat would be of extreme interest as they could see where the U.K., as a medium-sized country fell down in comparison with both a very large country with very large resources and also with a small country with small resources.

The second point he would like to make was one which, to his mind, illustrated that Air Commodore Banks' background had largely been concentrated on the engine side, and perhaps the grass appeared greener when one looked at the airframe side. He said in the paper that where engines were required for a given job one should not have just one engine type, because there were several different ways of doing it and it might possibly prove more efficient to do it one way rather than another. They could not be sure, therefore, and they had better have two types of engine. They would each cost 8 million pounds to develop and take five years. Nonetheless, according to the lecturer, they still ought to have two types available. But when it came to the airframe, apparently the decision should be based on theory and wind tunnel data only, and a definite choice of one airframe design and one only should be made right at the outset. He thought that the discrimination between airframe and engine problems was unreal. If there were any justification for one airframe design only for a given range of tests, then there was also as much justification for one engine design, too.

AIR COMMODORE BANKS: When he made his verbal reply to Dr. Hislop he did not have in front of him the information that he had gathered on the Royal Swedish Air Force, and he was perhaps too economical in the wording of that part of his lecture. He should have said that Sweden appeared to have a very clear-cut idea of the role and the requirements of her Air Force, and had planned a compact research and development organisation which, with good programming within her technical capacity, had resulted in Swedish-built equipment of excellent quality and performance. When speaking of equipment, this did not only mean the airframe but must include the armament and the ground facilities that were absolutely complementary to the efficiency of any Air Force. These facilities included the underground tunnels and hangars which had been constructed and from which, he believed, they could directly fly their machines.

It was quite obvious that the role of the Royal Air Force was more varied and, in consequence, its flying equipment more comprehensive than that of the Royal Swedish Air Force. But this was all the more reason for careful planning and a positive goal, which latter had been reached by Sweden expeditiously and with the minimum of hesitation in the process.

In 1954, some 80 per cent of the Swedish Air Force consisted of high performance swept-wing aircraft—the Saab J29. In fact, it was the first Air Force in (Western) Europe equipped with swept-wing machines. The J29 exceeded its design speed.

There was now the Saab-32 Lansen machine, a "transonic" two-seater, which had a multi-role as an all-weather fighter and reconnaissance machine. In addition, it was being produced as a dual control operational trainer,

The Draken (J35), which was a supersonic fighter, was now being tooled up for production and would probably go to the squadrons towards the end of 1957.

An excellent paper entitled "Aeronautical Research in Sweden" was given by Mr. Lundberg before this Society and was printed in the JOURNAL of October, 1955.

Swedish procurement was polished and economical, and, in his opinion, could serve as a good pattern for their own procurement. Production was arranged so far as possible to overlap the introduction of a new type. Each year, a new seven-year plan was agreed by the Government. For the 1956/63 period Sw. Cr. 3656m. (£252m.) were made available, and for 1957/64 the figure had been increased to Sw. Cr. 5076m. (£350m.).

He was informed that the present strength of the Swedish Air Force was 50 Squadrons, made up as follows:

10 Wings of 3 squadrons of day fighters.
1 Wing of 3 squadrons of night fighters.
4 Wings of 3 squadrons of strike fighters.
and 5 Squadrons of reconnaissance aircraft.

He would say that on a cost "per capita," or any other basis, Sweden had more for her money in the Air Force she had built up than almost any other nation.

On the second point raised by Dr. Hislop, regarding the statement inferring a duplication of engines but not of airframes. In the early days and before there was any real design know-how on the gas turbine engine, at least two of the various engine manufacturers were always asked to meet the same requirement, *i.e.* Goblin/Derwent, Ghost/Nene and Avon/Sapphire. In the post-war period, while engine manufacturers might have been asked to produce engines of similar thrust they had not necessarily designed similar engines to obtain the end result—since there were several ways of getting the thrust and at the same time obtaining an improvement in fuel consumption, *i.e.* the high pressure ratio, two-spool engine and the by-pass. Further, there had been some engines designed purely for the high speed (supersonic) fighter. The Gyron was a case in point. In other words, while one might go for, say, two bomber designs to meet a new requirement (and he had said that two projects were permissible at the start), there were a variety of aircraft types which could not all be satisfied by the same engine—although in a few years' time it might be possible to effect some reduction in the number of engine types by the modification of one or two to meet different aircraft requirements.

K. W. CLARK (Ministry of Supply, *Associate Fellow*): He only spoke because he was the A.D. Projects referred to in the text, and to say a word about consideration of "future systems." The paper might give the impression that they came straight out of the Air Staff's mind. That was not quite correct. They had in the past been considered by the Air Staff in very close collaboration with the Establishments and all aspects of the weapon system had been considered. But they hoped in the future, under their new chief Mr. Handel Davies, for even better consideration of the future systems.

The other point he wanted to make was the delays and changes in policy which seemed to hold up aircraft generally. He thought quite a lot of them stemmed from changes in personnel because the Air Staff Officers who advised on requirements, although the best people had been picked, were only in office in the Air Staff for about a couple of years and when they had really learnt to understand it they were posted to some operational station overseas. Other delays and changes came from the political considerations, the change in the Government, sudden panic on the part of the Treasury to cut back costs and other factors that were really outside the Air Ministry and Ministry of Supply organisation.

AIR COMMODORE BANKS: He did not intend to convey that the idea of "future systems" came directly from the minds of the Air Staff; but, whatever their origin, systems now formed an integral and complex part of the military aircraft requirement and must be considered from the very start. A complete weapon system for, say, an attack aircraft, or even that for an air superiority fighter, would appear to take as long to develop and bring to a state of readiness as the airframe and engine. Therefore, the appointment of Mr. Handel-Davies was, to say the least, timely for co-ordinating all these needs.

F. T. JONES (*President*): He thought the real sting in Air Commodore Banks' paper was in fact in the tail. He said, in the earlier part of the paper, that there should possibly be a combined Air Ministry—Ministry of Supply Technical Group to work on military requirements, etc. Then in the tail of the report he defined what sort of technical qualifications these people should have, and the only establishment that he could use to illustrate the desired qualities was an Army establishment. He did not know whether he meant by that that the Army should take over the Air Ministry job of coining the R.A.F. requirements!

AIR COMMODORE BANKS: He would thank the President for chairing this lecture and for his kind remarks about him. In reply to his latter comments, regarding the technical qualifications of officer personnel dealing with operational requirements: he would think that a judicious mixture of Henlow and Shrivenham training, coupled with an operational background, would be a very good basis for those forming the "Air Matériel Command" which he had suggested as a necessary part of the Royal Air Force procurement.

R. H. WEIR (Deputy Director-General of Engine Research and Development, M.o.S., *Fellow*) *contributed*: Rod Banks had such a wide experience that it was easy to see why the Lectures Committee selected him to speak about aircraft. So much so that he could escape by professing "ignorance" of anything other than his beloved engines. He thought he deserved to be congratulated on his provocative paper.

In his "new look" M.o.S. or Ministry of Aviation Rod suggested that key positions should be occupied by "a few senior administrators from the outside." Presumably, "the outside" meant the Aircraft Industry which

earlier he told them "was not alive early enough to the implication of the new look in aircraft and failed to prepare itself for the much greater technical needs of the day." How then could he expect this Industry to provide even a few key men to run his new Ministry of Aviation?

He was glad Rod had emphasised once more the importance of engine development. He thought he would agree that an engine usually required sizable development funds for more than five years and that the total sum expended on development might well be more than £8m. This strengthened his subsequent argument, of course.

He was personally very conscious of the need for close integration of engine and aircraft in future designs, and all this implied. (They already had some experience in this direction, of course, due to the past refusal, rightly or wrongly, of their aircraft designers to fit pods!) He doubted if they could afford nowadays to start full-scale engine development much in advance of specific aircraft. In many cases giving the engine "lead time" would only be possible by delaying the start of the aircraft and would therefore add to the overall time scale. He thought the engine industry must accept the challenge to design and develop engines more quickly. He thought they could do this and meet prototype aircraft (the critical date) with a reliable engine—but only if they had full support from up-to-date Engine Ground Test Facilities to supplement their Fying Test Beds in the air.

AIR COMMODORE BANKS: He was in entire agreement with Bob Weir's remarks and would reiterate that they had little to excuse themselves for in their aero-engines. But the aero-engine industry could depend only upon a healthy aircraft or airframe industry, and there was the risk of eliminating potentially good engines if there were no aircraft in which to install them.

A. E. WOODWARD-NUTT (Ministry of Supply, *Fellow*) *contributed*: Air Commodore Banks asked for a substantial reduction in the time taken to bring military aircraft into service from the time of the original conception. There had been so much vague speaking on this subject that when it was again raised one looked immediately for specific proposals by which a reduction in the overall time could be achieved.

In this case these seemed to be:

(*i*) Reduction of the time taken in formulating a requirement and getting it out to industry.

(*ii*) A more thorough assessment both of projects submitted by firms, and of firms' capabilities to design, develop and produce aircraft, and the allocation of contracts largely on this latter basis.

(*iii*) Conversion of the Ministry of Supply into a Ministry of Aviation, in which "key positions in the engineering and production sections" should be filled by "a few senior administrators from the outside," presumably from industry.

(*iv*) Expansion of the resources generally available in industry, and in particular, increased attention to wind tunnel testing.

There could be little disagreement about (*i*) so far as the time taken in administrative matters, financial clearances, etc. was concerned, although the very magnitude of the expenditure involved in modern weapon systems, and the limited number of projects which could therefore be undertaken meant that in the national interest authority had to be obtained at a very high level.

They should be cautious, however, about reducing too drastically the time spent in trying to ensure that the requirement, once formulated, was the best compromise between the demands of the Services based on their appreciation of the potential enemy's capabilities and the optimistic predictions of enthusiasts on the potentialities of new equipment. He was not sure where the lecturer stood there, for at one point he advocated putting the whole problem to the Aircraft Industry in very broad terms, whereas later he stressed the importance of the operational requirements team at the Air Ministry and those in M.o.S. who had to submit the requirements to industry, working very closely together on the details of the requirements. His own view was that there should be the fullest consultation between all concerned, including industry, at a very early stage, to weigh up the broader aspects of the problem, but that the requirement when issued should be quite specific on such matters as whether a manned or unmanned aircraft was required, its approximate performance, and the ground environment in which it had to operate, while leaving designers as free a hand as possible within this kind of limitation.

As regards (*ii*), assessment of firms' projects and of the potentialities of industry, much was being done in this field, and more was likely in the future. They were certainly far more aware than they were of the magnitude of the resources needed to produce a modern aircraft weapon system.

He would not comment on (*iii*), the suggestion of a "new look" Ministry of Aviation, with administrators from "outside" in key positions, except to say that he felt that the name of the Government Department(s) inevitably concerned was not a major issue. The main need was close contact and consultation between those who evolved a requirement and those who had to meet it.

He thought that point (*iv*) about the expansion of the resources available in industry was now widely appreciated, as was the importance of adequate wind tunnel testing and the more extensive use of electronic computing machinery, although the British Aircraft Industry had still a long way to go in this field.

There were, of course, other factors which affected the time of development and production of aircraft. Important among these was all the full-scale flight and structural testing work, and the smooth evolution from development into production aircraft. In both these fields they hoped that the Development Batch system of ordering military aircraft, now being adopted in this country, would result in a considerable reduction in the overall time of evolution of fully equipped operational aircraft.

One minor point: the lecturer was not quite accurate in saying that there had not been, until recently, a

Service requirement for propeller-turbine aircraft. The propeller-turbine Harvard replacement trainers to which he referred earlier were of course built to meet a Service requirement, but did not go into production in that form, and there was also the Gannet, which had been in Naval use for some time and for which the specification was drawn up in 1945. However, none of the British propeller-turbines at present in, or proposed for, civil aircraft had had any military background.

AIR COMMODORE BANKS: He was very pleased indeed to have Mr. Woodward-Nutt's remarks and he judged from these that they were not greatly in disagreement. On this last point, regarding a Service requirement for a propeller-turbine aircraft: while it was true that such an engine was proposed for the Harvard replacement it was never adopted for the trainer which eventually went into service (the Balliol), principally because a trainer airframe could be designed and built very quickly whereas, at that time, this type of engine was entirely new and very expensive. But this lent some point to his argument: that if there were a Service requirement then civil aviation could greatly benefit as the result, *i.e.* as from the Dart engine which, with the Mamba, evolved from this original need.

CONCLUDING REMARKS TO THE DISCUSSION

In reviewing his lecture and what had been said in the resulting discussion, he was more than ever convinced that he did not over-state the case and was not alone in thinking that their military aviation was in a relatively poor state of health. But it was the future which really gave cause for concern, since the present rate of "progress," when coupled with advances elsewhere, might have really serious effect from about 1960 onwards.

He was equally sure that, if they "pulled their socks up," they could, by 1960, see a promising future for a not too limited effort in both the military and civil fields. But, to ensure this, there would have to be an immediate improvement in procurement policy—if any real policy in fact existed today.

The first thing to establish was a longer term budgetary plan. The present yearly budget, which seemed to be under continuous (monthly) review from the financial angle, was quite unrealistic; and a seven-year plan, reviewed yearly and adjusted accordingly, should be accepted by the Cabinet and the Treasury in order to allow the Air Ministry, the Ministry of Supply and the Industry to achieve and maintain a steady rate of progress.

He suggested seven years rather than the five years inferred in the lecture, since they were now moving into the supersonic, and even the hypersonic, era and aircraft and weapons would take longer to evolve than their subsonic counterparts.

The decision which proved almost fatal to their post-war fighter progress was that made at the end of the War, to embark upon supersonic research by dropping models from Mosquito aircraft and telemetering the results. This misguided effort had probably cost them fifteen years in fighter development.

Further retardation of progress in fighters had been due to a post-war decision to reduce the number of prototypes ordered from a given design. While this situation was somewhat improved in 1954, the damage had already been done.

In the case of the bomber, and because of the great effort needed to design, develop and bring a modern bomber to production, little duplication was feasible and, therefore, the minimum number of prototypes was usually ordered. Hence the need for considerable and meticulous preparatory work in the design and experimental phases. More wind tunnel work was done in a year by Boeing on the B-47 than the total achieved in the past ten years in this Country. Maybe this effort was really needed for that machine, but the firm had the facilities and used them to the full.

It was imperative that the Royal Air Force be kept efficient and strong. Its role today was similar to that of the Royal Navy in earlier times, where "a Fleet in being" was not a threat to other countries but a deterrent to any country that meant mischief. While he did not know what their requirements should be, it would seem that a "transonic-supersonic" fighter, of about a Mach number of 1·5, was needed for air superiority in the event of a conventional and area-limited "hot" war, with one of $M = 2{\cdot}5—3{\cdot}0$ as a bomber attacker, or defensive, aircraft. Only when a fully tried ground-to-air guided weapon had been in service use for some years could the fighter fade out of the picture. It would be dangerous in the extreme to their defence if the development of such fighters were stopped, whatever the present promise of the guided weapon—or the I.C.B.M., which might at some future date make the bomber obsolete.

He would conclude by quoting two paragraphs from *The New Statesman and Nation* for 8th September 1956:

> "We are in fact in the middle of one of those crises that are hardest of all to cope with. This is an invisible crisis: nothing dramatic is going to happen for years: all we shall hear are warnings on the Third Programme from Sir Francis Simon mixed with bland reassurances from others that things are not quite what they seem. Then we shall wake up and find, like Venetians in the 17th century, that all that makes our living has slipped away. The whole scientific-industrial world is going through a change for which we have not yet found a name: to emerge from that change successfully will require many things, but above all scientists in numbers which neither we, nor even the U.S., have begun to train.
>
> "This crisis has been growing on us for a good many years. It was already clearly visible—and a few people said so—in 1945. But it is no use handing out blame to those who would not attend because that means nearly everybody. It is very difficult to alter radically a pattern of education as complex, as deeply rooted, as intricate in its class structure as ours. The patterns of education are tied to the past of each of us; any deep change brings something of the strain and feeling of a family quarrel. For that reason, in a society like ours, it may turn out to be impossible to make a deep education change in time. But we ought to know what will happen if we do not."

Methods of Reducing the Transonic Drag of Swept-Back Wings at Zero Lift*

by

D. KÜCHEMANN, Dr.rer.nat., F.R.Ae.S.

(Royal Aircraft Establishment, Farnborough)

This note gives a brief review of the physical argument behind the methods developed at the Royal Aircraft Establishment for reducing the normal-pressure drag of swept-back wings of moderate or large aspect ratio in the transonic flight range. The potential benefits of sweep are recalled; the causes for drag forces arising are discussed; and means of reducing the drag are described.

1. Drag Forces in a Displacement Flow

The purpose of this paper is to review briefly some means of reducing the normal-pressure drag at transonic speeds of wings and wing-body combinations without lift. By transonic speeds is meant here not only the range of main stream Mach numbers around unity but, more generally, that speed range where a transonic type of flow around the body may exist. Thick non-lifting bodies as are considered here cause a displacement flow and it may be recalled that at least three different types of flow are involved: a subsonic, a transonic, and a supersonic type of flow, all of which are here assumed to have one attachment line along the leading edge and one separation line along the trailing edge. This excludes types of flow where separations occur elsewhere, such as shock-induced separations along some line within the wing chord.

A displacement flow arises when a body of given volume is propelled through the air so that air particles are pushed out of the way. As the velocity of an air particle relative to the body changes along its path, the pressure on the surface of the body changes and in all three types of flow the air is first compressed, then accelerated and finally compressed again. In the subsonic type of flow, the two compressions are such that the corresponding normal-pressure forces on the body cancel each other and whatever forces may result from suction forces in the region of accelerated flow, so that no overall drag results. In the supersonic type of flow, the two compressions are achieved through compression waves, which usually condense into strong shocks. The compression and expansion waves are often such that a pressure greater than the ambient pressure results over most of the forward-facing surfaces of the body and, that a suction force results over most of the rearward-facing surfaces. This, of course, produces a large normal-pressure drag. A transonic type of flow, then, is a mixed flow where regions with a subsonic type of flow appear simultaneously with regions with a supersonic type of flow.

In the subsonic type of flow, the main interest lies not so much in the drag forces themselves—the overall drag must be zero, anyway—but in the limit of the flow régime where it begins to change into the transonic type of flow. Now, as is well known, the subsonic type of flow obeys an equation of motion which is of the elliptic type for an inviscid medium, whereas the transonic and supersonic types of flow do not. Hence, the end of the subsonic flow régime can be defined when it is known where the equation of motion changes its type. Here we come upon the first advantageous property of swept wings in that a subsonic type of flow can, in principle, be preserved up to higher flight Mach numbers than on unswept wings, and even into the régime of supersonic main stream speeds. Küchemann and Weber[1] (1953) have shown that the equation of motion changes its type when the velocity component normal to an isobaric surface reaches the local velocity of sound. Defining the main stream Mach number at which this happens, *i.e.* where the critical pressure coefficient, C_p*, is reached, as the "critical Mach number", it is found, as is demonstrated in a typical case in Fig. 1, that on a sheared wing of infinite span the critical Mach number can be raised from point B_0 for an unswept wing to B_1 or B_2 according to the angle of sweep used. This diagram, incidentally, also indicates the other advantages of swept wings, namely, that the perturbation velocities are smaller than on the corresponding unswept aerofoil with the same section along wind, at zero Mach number, and that the rate of change of the pressure coefficient with Mach number is also smaller. (There is, however, no simple "$\cos\varphi$-law" to describe these properties, as is often presumed.) A very simple way, then, to keep the drag of wings small at transonic speeds is to design them so that sheared-wing conditions are approached as closely as possible. In other words, we attempt to preserve a subsonic type of flow where the normal-pressure drag can be zero.

In the transonic type of flow, a shock wave will usually occur within the wing chord and the normal-pressure drag cannot be zero. For the case of a two-dimensional unswept aerofoil, Warren[2] (1956) has recently given a detailed description of this type of flow, the transonic type of flow beginning when the first supersonic region is formed locally somewhere on the body surface, and ending when the upstream shock is attached to the leading edge and the downstream shock

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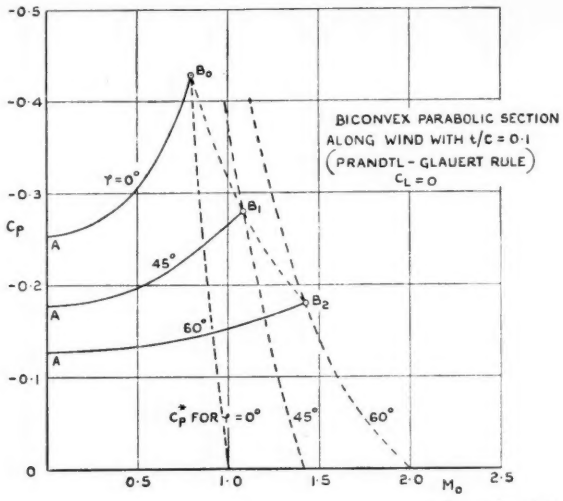

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FIGURE 1. Pressure rise up to the critical Mach number for sheared wings of infinite span.

to the trailing edge. A simple model of the transonic type of flow has been suggested by Küchemann and Hartley[3] (1955), which can be best explained by considering the local Mach number distributions along a two-dimensional aerofoil from experiments by Holder, Pearcy and Gadd[4] (1954), as shown in Fig. 2. The measured curves are compared with the dotted lines which have been calculated for a "shockless" inviscid, *i.e.* subsonic, type of flow obtained by scaling up the incompressible velocity distribution according to the Prandtl-Glauert rule, say. It will be seen that the measured Mach numbers behind the shock approach those for the shockless flow. The drag of the aerofoil is thus related to the chordwise position of the shock. This can be estimated if its direction is known and if the physical hypothesis is introduced that the pressure rise through the shock in the external predominantly inviscid stream at the edge of the viscous region is limited by what the viscous region itself can muster by means of turbulent mixing, such that the pressure-rise coefficient

$$\sigma = \frac{p_2 - p_1}{\frac{1}{2}\rho_1 V_1^2}$$

does not exceed a certain value which may, among other things, depend on the state of the boundary layer (roughly, σ is about $\frac{1}{2}$ for turbulent layers and about $\frac{1}{3}$ for laminar layers upstream of the shock). For example, if the shock lies in a plane normal to the main stream,

$$\sigma = \frac{p_2 - p_1}{\frac{1}{2}\rho_1 V_1^2} = \frac{4}{k+1}\left(1 - \frac{1}{M_1^2}\right),$$

which gives for the upstream Mach number

$$M_1^2 = \frac{1}{1 - \frac{k+1}{4}\sigma} = \frac{1}{1 - 0{\cdot}6\sigma}$$

for $k = 1{\cdot}4$. We have $M_1 = 1{\cdot}2$ for $\sigma = \frac{1}{2}$, independent of the main stream Mach number, M_0. This "ceiling" of the upstream Mach number has often been observed. The local Mach number downstream of the shock is then also independent of M_0. This model of the flow is roughly confirmed* by the experimental results[4]. Evidently, the shock accommodates itself in such a way that, at the boundary of the viscous region, the pressure rise in the external stream is compatible with the pressure rise through mixing in the viscous region and that the downstream pressure smoothly joins into a pressure distribution which is governed primarily by the then shockless external stream. Thus the backward movement of the shock, as the main stream Mach number is increased, is rapid over the flat portions of the fictitious shockless Mach number distribution and is considerably retarded when the pressure rise steepens. This model offers at once a means of reducing the rate of drag rise in the transonic type of flow. Since the drag is generally the greater the farther back the shock is, the basic shockless pressure distribution of the aerofoil should have its suction peak near the leading edge so that the pressure rise, and hence the initial shock, begins as far forward as possible and that the rate of pressure rise is nearly uniform. Then, the shock will be farthest forward and the drag lowest.

In the supersonic type of flow, the comparatively large normal-pressure drag resulting from two strong compressions near the leading and trailing edges could obviously be reduced if it were possible to replace each of the discrete shocks by a greater number of weaker shocks, ideally by an infinite number of infinitely weak shocks, *i.e.* by a "shockless" isentropic compression. A shockless compression has been advocated for a number of diverse applications, for instance for air intakes, and could, in principle, be used for wings also. In fact, designs according to the various forms of the "area rule" of Whitcomb[6] (1952) often rely on achieving such shockless compressions in order to keep the normal-pressure drag low. However, the flow in all such calculations is assumed to be inviscid and the boundary conditions are taken on the surface of the solid body. In reality, the flow can at best be assumed to be inviscid only outside a viscous region which envelopes the body and forms a wake behind the body. The boundary conditions for the external inviscid stream must then be taken at the edge of the viscous region from the solution of the viscous flow in that region. Now, it can be shown that, in certain cases, the flow in the viscous region cannot be without shocks even if an isentropic compression is possible in the external inviscid stream. This means that the solution obtained for the inviscid external stream will not occur in practice. In fact, shocks will be formed both in the external stream and at the fringe of the viscous region. This explains why it has been impossible so far to achieve a shockless compression in many cases with a real fluid, and this often makes the intended drag

*That the downstream Mach number is not near 0·85, as it should be for a normal two-dimensional shock, is probably due to the facts that the shock is of limited lateral extent and that it is immediately followed by an expansion due to the increase of displacement thickness of the viscous region; *see* Holder[5] (1955).

reduction illusory. There is one exception, however, namely, when the compression takes place over a swept wing. In that case, the flow can be subsonic in type even in a supersonic main stream and viscosity does not normally upset the shockless flow. Swept wings thus deserve further consideration.

2. Three-Dimensional Effects

Now a real swept-back wing differs from the infinite sheared wing considered so far in two main respects:— it is composed of two sheared wings put together with a kink at the centre line and it has a finite span. Whereas the streamlines over a sheared wing are curved, this curvature is smaller at the wing tips and disappears altogether at the centre line. Thus the interference effect between the two wing halves and the tip effect both prevent the " sheared-wing-flow " from being preserved over the whole wing. The potentialities of sweep are then by no means realised, and the actual drag of a swept-back wing is always found to rise above its low-speed value at some subsonic main stream Mach number and to be quite considerable when the critical Mach number of the corresponding sheared wing is reached. These setbacks are largely due to the three-dimensional nature of the flow.

As so often nowadays, we must realise that two-dimensional flow is highly exceptional. On any truly three-dimensional wing or body, even in incompressible flow, the normal-pressure drag is not, as a rule, zero at every streamwise section. The overall drag is zero only

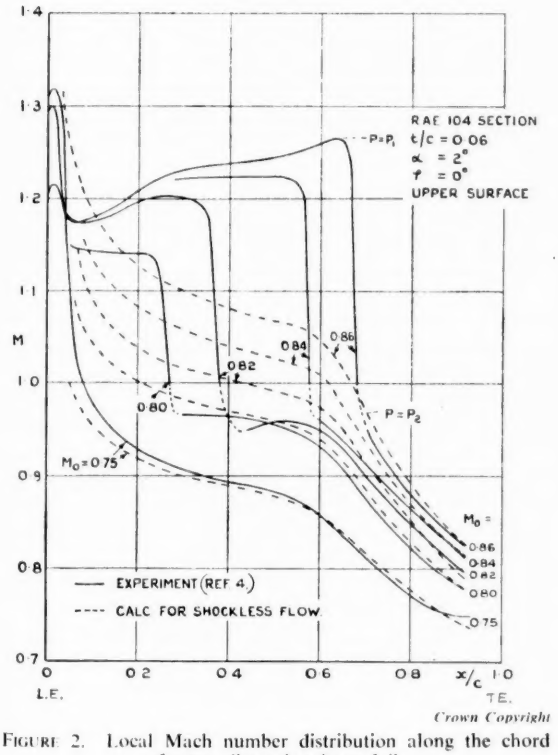

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FIGURE 2. Local Mach number distribution along the chord of a two-dimensional aerofoil.

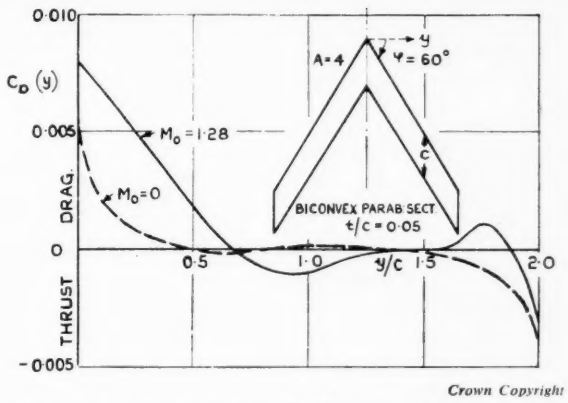

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FIGURE 3. Calculated drag distributions along span for a swept-back wing.

because sectional drag forces somewhere are counterbalanced by sectional thrust forces elsewhere. The conventional swept-back wing is a typical example. There is a drag force in the central region and a thrust force in the regions near the wing tips, forming a couple which tends to reduce the angle of sweep, as shown in Fig. 3. In this particular case, the thrust and drag regions do not overlap and there is a region near mid-semispan where no forces occur and where, indeed, the conditions of the infinite sheared wing are approached. Within these limitations, then, " sheared-wing conditions " have still a physical meaning. Such local drag and thrust forces persist in supersonic flow and Fig. 3 gives an example where the leading edge of the wing is within the Mach cone and where, again, no drag forces occur on a " sheared part " of the wing somewhere between centre and tip. But now the centre drag due to the kink is not counterbalanced by thrust forces near the tips. In fact, the tip regions themselves contribute no overall force in this case, which is typical. Thus the overall drag of the wing is not zero, and we note that it arises from a normal-pressure drag due to the kink in the central region, the local drag being highest at or near the centre section itself.

It is of some interest to note that the drag at the centre section arises, for both the subsonic and the supersonic types of flow, from a term in the velocity distribution, which is proportional to the local slope of the aerofoil contour in wind direction, *i.e.* from an " Ackeret term ", as shown in Refs. 1 and 3. For an untapered swept-back wing of an aspect ratio that is large enough to leave the centre effect unaffected by the tips, we have

$$C_D = \frac{4}{\pi} \frac{\cos \varphi}{\sqrt{(1 - M_0^2 \cos^2 \varphi)}} \ln \left| \frac{\sqrt{(1 - M_0^2 \cos^2 \varphi)} + \sin \varphi}{\sqrt{(1 - M_0^2 \cos^2 \varphi)} - \sin \varphi} \right| \times \times \int_0^1 \left(\frac{dz}{dx} \right)^2 dx$$

from linearised theory, for subsonic and supersonic Mach numbers with both subsonic and supersonic leading edges. M_0 is the main stream Mach number, φ the angle of sweepback, and $z(x)$ the shape of the

aerofoil section. For a biconvex parabolic section of thickness-chord ratio t/c,

$$I = \int_0^1 \left(\frac{dz}{dx}\right)^2 dx = \frac{4}{3}\left(\frac{t}{c}\right)^2 ,$$

and for a double-wedge section, $I = (t/c)^2$. These drag forces can obviously be quite considerable, and the overall drag depends on a very delicate balance between the various thrust and drag forces, which in themselves may be much larger than the final overall value.

The distortion of the sheared-wing flow at the centre of a swept-back wing due to three-dimensional effects, of which these drag forces are an indication, is responsible for the limitation of the régime with a subsonic type of flow because of loss of isobar sweep and thus for the premature drag rise; it is also responsible for the comparatively high drag in the régimes with transonic and supersonic type of flow. An attempt is, therefore, indicated to reduce this centre distortion. If successful, this should have a beneficial effect in all three flow régimes. It is possible too that if the critical Mach number at the centre section is raised, then the transonic drag rise can be less steep; and if the subsonic type of flow is maintained up to a higher main stream Mach number, then the transonic type of flow, too, is likely to be maintained up to a higher main stream Mach number. Where the drag reduction is most needed determines the design Mach number; but the greatest drag reduction from such modifications (to reduce the centre distortions) is to be expected near the critical Mach number of the corresponding sheared wing. This has largely been confirmed by experiments, and it explains why the application of the "sonic area rule" has been successful in many cases where, as it happened, the critical Mach number of the corresponding sheared wings was not far from unity.

3. Means of Reducing the Drag

Actual methods for designing such modifications include changes in the plan form or the aerofoil section of the wing and the addition of other bodies to obtain a favourable interference: such methods have been discussed in Refs 1 and 3 and Haines[7] considers the particular aspect of the wing design. We restrict ourselves here to the basic case of wing-fuselage combinations and we shall thus ignore possible changes in the wing shape and, in particular, conditions at the wing tips, assuming that the wing tips have been properly designed by other methods.

With wing-fuselage combinations, two different flow fields are superimposed upon one another. This gives a far greater variety of choice and the chance of using the interference between two bodies to advantage. In a supersonic type of flow, for example, two flow fields may be used to blot out the drag-producing wave systems altogether, as in the classical cases of the Busemann biplane and the ring wing with central body of Ferri and Ferrari (*see e.g.* the paper by Graham, Beane and Licher[8] on this subject.) A long fuselage and a thin wing across it cannot, of course, be matched

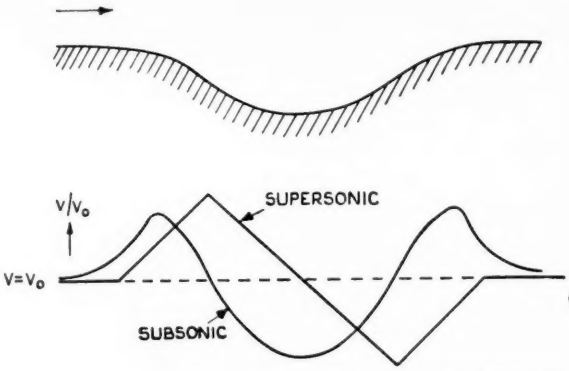

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FIGURE 4. Velocity distributions along a two-dimensional curved wall (schematic).

with such an efficiency; for this their flow fields differ too much in all three types of flow under consideration. A fuselage will, for instance, introduce a wave system of its own on its forebody and on its afterbody and this cannot easily be used to interfere favourably with the wing. We may assume here that the fuselage is long enough and slender enough for these waves not to interfere with the wing and for the associated wave drag to be small. The basic fuselage may then be taken as cylindrical within the wing region. This is then modified so that a curved intersection line results between fuselage and wing where the velocity distribution satisfies some required conditions. If the fuselage were very high and could be considered as a vertical wall of infinite extent, then it should be curved in the same way as the streamlines of the infinite sheared wing in order to restore sheared-wing conditions everywhere. With real fuselages, other junction shapes will be required and the degree of success of such a modification then depends on whether the influence of the fuselage reaches far enough out and can satisfy the required conditions also away from the junction. Obviously, a very small body with its diameter small compared with the wing chord cannot affect the whole region where the wing flow is distorted by the centre effect and will thus be less effective than a body with a larger diameter.

The first and obvious possible way to shape the fuselage junction is that which restores the sheared-wing velocity distribution in the junction, the design Mach number being the critical Mach number of the sheared wing. In this manner the characteristics and the subsonic type of flow of the ideal sheared wing can be realised at the design Mach number, and the normal-pressure drag of the wing can then be zero. There remains only the drag force on the fuselage itself; this does not necessarily exceed the forebody and afterbody drag by an appreciable amount, and these can be kept small. Hence, such a design keeps the overall drag near its smallest possible value for a given wing and body size.

We can see at once what kind of junction shape will result in such a design. The centre effect of swept-back wings, in all three types of flow, is always such that the velocities are lower over the forward-facing surfaces of

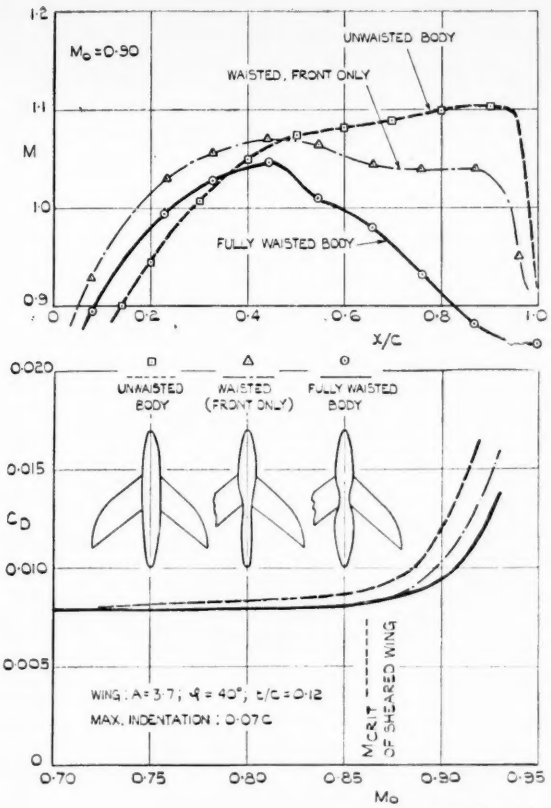

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FIGURE 5. Measured local Mach number distributions and overall drag of Hartley's models.

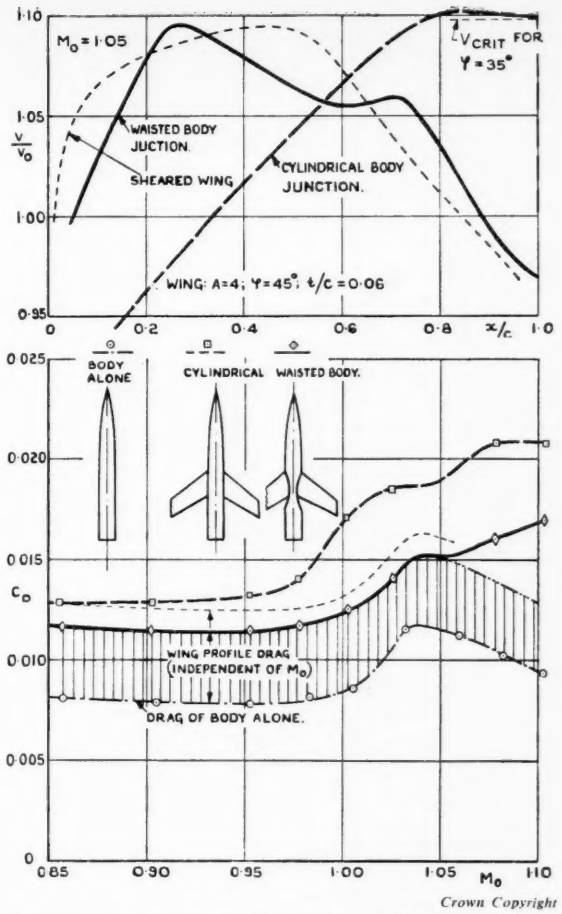

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FIGURE 6. Calculated velocity distributions and measured drag of Whitcomb's models[6].

the wing section and greater over the rearward-facing surfaces than they are on the sheared wing with the same aerofoil section. Hence, the junction shape must be such that the velocity is raised over the front part of the section and reduced over the rear part, so as to compensate for the Ackeret term. This seems plausible, physically, since, by raising the suction forces over the forward-facing part of the section and increasing the pressure over the rearward-facing part, the normal-pressure drag is obviously reduced. The shape of the side wall of the body to achieve this must always be a waist-like indentation, both at subsonic and at supersonic main stream Mach numbers, as can be seen from Fig. 4. One can almost state that any waisted fuselage suitably placed on any wing is likely to lead to some drag reduction at transonic speeds. Conversely, conventional convex fuselage shapes, which bulge outwards, make matters worse.

A waist-like indentation, which swings out again and forms a bulge near or behind the trailing edge of the wing, is also of the kind required to reduce the drag rise, once the critical Mach number has been exceeded and a transonic type of flow established, because it tends to delay the rearward movement of the shock wave on the wing by increasing the pressure over the rear part of the section in the calculated shockless pressure distribution. Such waisted junction shapes can, therefore, be effective also on unswept wings in reducing the drag at transonic speeds when a transonic type of flow must exist. For unswept and for swept wings, a waisted fuselage may further be used to reduce the whole velocity level over part of the wing, which will be especially effective on highly tapered wings. In this way, the critical Mach number can be raised and the drag reduced in the transonic and the supersonic type of flow, the wing behaving in some respects like a thinner wing.

The present line of approach to remedy the shortcomings of swept wings was taken up in 1942 soon after their beneficial properties had been demonstrated by Betz[9] and Ludwieg and as soon as it was realised how the central kink or the addition of a conventional fuselage or engine nacelle distort the flow pattern associated with the infinite sheared wing (*see e.g.* Refs. 1 and 10, chapter 9). In the meantime, the design of suitable junction shapes has progressed from empirical methods involving tunnel tests and experiments with cavitation bubbles to analytical methods. Hilton[11] (1955) has proposed a similar method, restricting himself, however, in the main to the use of the streamlines of the infinite sheared wing. It remains to show how effective these methods are in practice.

4. Experimental Confirmation

Experimental results for two examples are given in Figs. 5 and 6. The first case is a 12 per cent thick wing of 40° sweepback with a critical Mach number of the

corresponding sheared wing of about 0·86. In this case, the junction shape was calculated by Hartley to have the same velocity distribution as the sheared wing and this was reasonably well achieved. The second case is a 6 per cent thick wing of 45° sweepback with a sheared-wing critical Mach number of about 1·12. In this case, the junction was not calculated to have a specified velocity distribution. The model was designed according to the sonic area rule by Whitcomb[6]. However, as it frequently happens (the series of possible area-rule shapes is always likely to contain one where the wing flow is subsonic in type), the junction shape is such as to give a reasonable, although not very good, approximation to the sheared-wing pressure distribution at the lower main stream Mach number of 1·05. The potential benefit of sweep was thus not fully realised with the model. Further experimental evidence in support of the present method can be found in tests by McDevitt and Haire[12] (1956).

In the first case, shown in Fig. 5, the distribution of the local Mach number as measured in the junctions of three different body shapes is given at a main stream Mach number of 0·90, which is beyond the critical of the sheared wing. The results in the junction with a cylindrical body are typical of the transonic type of flow; they clearly indicate a large supersonic region with a shock nearly at the trailing edge, implying a considerable increase in normal-pressure drag. A waisted body where only the front part of the calculated junction shape had been realised on the model was effective in raising the critical Mach number (because the peak-suction line was fully swept), but the super-critical drag rise was not much reduced. Thus, at $M_0 = 0{\cdot}90$, a supersonic region terminated by a shock was still evident. A fully waisted body, on the other hand, not only raised the critical Mach number but also reduced the transonic drag rise by a considerable amount. There is hardly a shock to be detected in the junction, even though shocks farther out on the wing had been observed at this Mach number. The drag distribution along the span, as compared with the normal type shown in Fig. 3, has thus actually been reversed by the body shaping. It may be noted that the drag reduction obtained by proper junction design is equivalent to either an effective increase of the angle of sweepback from 40° to about 45° or to an effective reduction of the thickness-chord ratio of the wing from 12 per cent to about 10 per cent.

In the second case, shown in Fig. 6, a considerable increase in drag is to be expected from the calculated velocity distribution in the junction with the cylindrical body, whereas the flow can obviously be subsonic in type in the junction with the waisted body, even if the effective isobar sweep is only 35° instead of 45°. Consequently, there is evidently no wave drag at all on the wing itself up to $M_0 = 1{\cdot}05$, the measured drag being accounted for by the body drag and the profile drag of the wing if that is assumed to be independent of flight speed. This confirms that it is possible and worthwhile to establish a subsonic type of flow and thus to reduce the normal-pressure drag in the central region of a swept-back wing to zero up to near the critical Mach number of the corresponding sheared wing, even if the latter occurs at a supersonic main stream Mach number.

In conclusion, it would appear that the greatest improvements in the zero-lift drag of swept wings and wing-body combinations can be achieved in the transonic type of flow, with the design Mach number near the critical Mach number of the sheared wing; and that it will be more difficult to substantially reduce the normal-pressure drag once a truly supersonic type of flow has been established because, then, the flow fields of the body and of the wing cannot be properly matched. The swept-back wing, in particular, offers substantial benefits which, in view of the considerable aerodynamic and structural difficulties entailed in using swept wings, should be consciously exploited in a rational manner.

ACKNOWLEDGMENT

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On the Noise from Supersonic Jets*

by

Professor E. J. RICHARDS, M.A., B.Sc., F.R.Ae.S.

(University of Southampton)

IN PARALLEL with the work undertaken at the University of Southampton on the study of the noise from subsonic jets, a further investigation has been made into the noise from supersonic or choked jets. Whereas in the former case the noise is due to the turbulent velocity fluctuations and thus contains a wide spectrum of random frequencies, the latter case contains, in addition to this wide spectrum, noise caused by turbulence-shock wave inter-action.

Once the critical pressure ratio of a jet has been attained, *i.e.* that pressure ratio which produces sonic or supersonic flow in the jet pipe just before the orifice, the structure of the jet depends crucially upon the nozzle shape. For a nozzle of the correct orifice area the jet pressure may be brought to the outside pressure with shock-free flow: the jet is then said to be correctly expanded. For larger (over-expanded) or smaller (under-expanded) orifice areas the ensuing jet will contain shock waves: these shock waves are responsible for a considerable amount of the noise output of the jet as a result of eddy: shock wave inter-action.

The first experimental indication of the possible mechanism of such noise formation was reported at the A.S.A. noise conference at San Diego in 1952. The present paper gives a general description of the subsequent investigations, both experimental and theoretical, that have been made at Southampton, the investigation falling effectively into four parts:—

(1) An examination of the phenomenon of resonance in choked jets with regard to the frequency of the sound emission.

(2) An experimental and theoretical study of the inter-action between a shock wave and an eddy in the form of a discrete vortex, in order to establish the nature of the sound wave emitted, and to assess its dependence upon the parameters of shock strength and velocity perturbation.

(3) Noise measurements on cold jets using convergent-divergent nozzles, and

(4) An analysis of the effect of temperature fluctuations convected through a shock wave.

These will be dealt with in this order.

First the mechanism of jet resonance, or "back-reaction" noise. The photographs shown at the 1952 conference indicated the presence of discrete tones, and this has been explained in terms of a resonance mechanism. When an eddy moves downstream and inter-acts with a shock wave in the jet structure, a sound wave is produced which radiates into the surrounding atmosphere and has in particular an intense component in the upstream direction, *i.e.* towards the lip of the jet orifice. On meeting the lip of the orifice a further eddy is liberated due to the fluctuating pressure and this eddy then causes a repeat of the original cycle, the continuous process leading to regular liberation of sound waves which, at particular jet pressure ratios, gives rise to a note of a discrete frequency. The existence of such a note has also been confirmed by direct measurement[1] which shows the frequency of the note to be directly related to fluctuations in the jet stream.

In view of the mechanism by which this sound wave was thought to be produced, experiments have been made to examine photographically the inter-action between the simplest "two-dimensional region of turbulence", *i.e.* a vortex, and a shock wave, with particular reference to the production of a sound wave. These experiments have been carried out in a shock tube specially prepared for this investigation.[2] The shock wave was made to travel along the tube and then be reflected from the closed low-pressure compartment. In passing along the tube, the shock traversed an aerofoil placed at some positive angle of incidence, a trailing vortex being formed in the relatively slow moving stream behind the shock. Schlieren photographs were taken of the inter-action as the reflected shock passed through the vortex. The shock strength was varied by altering the initial pressure in the shock tube upstream of the diaphragm and the strength of the vortex was varied by adjusting the incidence of the aerofoil.

A typical Schlieren photograph showing the sound wave emitted is given in Fig. 1. The extraneous shocks to be seen result from reflections from the walls of various waves propagated at the aerofoil and end-plate, and are difficult to eliminate with the technique used. They do not affect the general inter-action pattern however, which indicates clearly the way in which a sound wave is emitted, the greatest free sound output being directed at angles towards the shock. The photographs, while being only of a qualitative nature, do nevertheless indicate two general trends which have since been confirmed theoretically, namely,

(*i*) The radiation downstream, away from the shock, is small compared with that upstream,

(*ii*) the strength of the sound wave appears to depend largely on the strength of the vortex and less on the strength of the shock.

*This paper was read at the Second International Congress on Acoustics, at Cambridge, Mass., in July 1956.

FIGURE 1. The sound produced from the inter-action of a vortex and a shock wave.

A theoretical treatment of the flow has been made[3] which in fact bears out the foregoing tentative conclusions. The method used is an extension of the method used by Ribner[4]. Although the method of analysis does not pretend to be analytically rigorous, the similarity between the theoretical pattern of sound emission and that photographed in the shock tube experiments allow some conclusions to be drawn with a fair degree of confidence. The sound wave originating from the inter-action is very intense, on an audio scale, for quite small vortex velocity perturbations; a mean sound level of 122 db is forecast for a 0·1 per cent fluctuation about the mean velocity at $M=2{\cdot}0$. For these particular calculations which refer[3] to the conditions behind a shock in a wind tunnel with atmospheric stagnation conditions, the sound pressure amplitudes depend linearily on the strength of the vortex velocity perturbations, whereas the shock strength has less effect. Indeed in this particular instance, the amplitude of the sound is reduced slightly as the Mach number forward of the shock increases above $M=1{\cdot}5$. It should be emphasised however, that the emitted sound depends greatly on the steady flow conditions which prevail in the tunnel.

As a tentative conclusion, therefore, *it may be stated that the noise emitted from the inter-action between the turbulence in a jet and the standing shock pattern depends primarily on the strength of the turbulence and less on that of the shock conditions, save for very weak shocks.* Thus unless the jet nozzle has been designed correctly for exactly the operating conditions, even the existence of slight shocks in the jet flow will give rise to large noise emission from the inter-action.

With this thought in mind, experiments have been made[5] to examine the noise emitted from a series of convergent-divergent nozzles designed to give the correct expansions equivalent to $M=1{\cdot}1$, $1{\cdot}2$, $1{\cdot}3$, $1{\cdot}4$, and $1{\cdot}5$. The experiments were done on small models of two inches diameter operating with cold air; consequently temperature effects were absent and the results have only limited application to full-scale jets. Nevertheless, the curves of overall noise levels so obtained are of great interest (Fig. 2). These all refer to a point situated at a distance of 4 ft. from the jet exit at an angle of 30° to the axis of the jet, normally the direction of greatest noise amplitude. It is seen that in every instance the overall noise level increases with the upstream stagnation pressure, except in the vicinity of the design pressure ratio, indicated on the curves by the Mach number arrow, where a definite dip is recorded. It should be pointed out that it was impossible to make accurately the $M=1{\cdot}1$ nozzle and that the minimum in this case did not occur at the correct pressure ratio. Taking, however, the variation on the $M=1{\cdot}4$ nozzle it may be seen that there is an overall reduction in intensity of 6 or 7 decibels at the station considered, over that for a normal convergent nozzle. For pressure ratios above this, however, the reduction quickly disappears. At pressure ratios lower than the design figure, the noise is again similar to that of the convergent nozzle, although at no stage is the noise greater and, sometimes it is less. It is dangerous to draw too many conclusions in this region since the noise from the normal convergent nozzles is susceptible to slight errors in shape, quality of edge and boundary layer thickness.

The main conclusion to be drawn, therefore, is closely associated with that of the shock tube experiments, namely that *an appreciable noise reduction can be obtained by using a convergent-divergent nozzle but that this reduction is confined to a small pressure ratio range around the correct ratio for that nozzle.* Away from these conditions, the shock patterns are sufficiently strong to allow noise emission from their inter-action with the turbulence passing downstream.

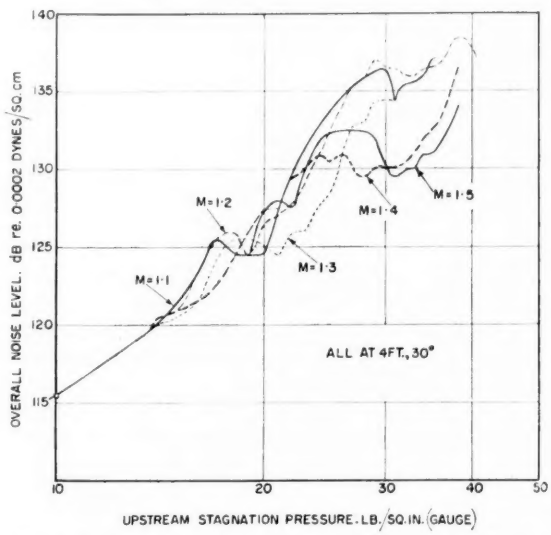

FIGURE 2. Overall noise level. Several convergent-divergent nozzles designed for different working pressure ratios.

Turning finally to the effects of temperature fluctuations in the jet, essentially a separate item to the previous discussion, it must be remembered that only results of a qualitative, theoretical, nature involving the inter-action of plane sound waves with a plane shock wave have so far been established[6]. Kovaznay has shown that perturbation in pressure, velocity, or temperature, each give rise to sound waves, temperature fluctuations and velocity fluctuations in the downstream flow after convection through a shock wave, and this has been further verified by Powell with particular reference to the production of sound waves.

The laws appertaining to this noise in one dimensional flow have been written down[6] in an attempt to establish the magnitude of this source of noise emission. In acoustic measures these fluctuations are capable of large noise emissions of a magnitude comparable with that due to turbulence. For example, if with a normal shock wave the upstream Mach number is 2·0, and the upstream conditions are atmospheric, *a 0·1°C temperature fluctuation will result in a pressure amplitude corresponding to 126 decibels sound pressure level (above 0·0002 dynes/sq.cm.).* It is clear therefore that temperature fluctuations are likely to be a source of considerable noise in choked jets of gas turbine engines, rockets, and so on, in particular where poor combustion occurs.

In conclusion, from the Southampton University work one may make the following predictions on the suppression of choked jet noise. First, a convergent-divergent exit nozzle will be of considerable help at, and only at, the particular design Mach number. If such a nozzle is designed for the condition of maximum thrust at take-off, it may go some way towards alleviating this particular problem, but under all other conditions the convergent-divergent nozzle will give no appreciable advantage. In these circumstances it is the "roughness" of the jet that should be improved, turbulence and temperature fluctuations due to rough combustion being responsible for a large noise output.

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TECHNICAL NOTES

Contributions to this Section of the JOURNAL *will be eligible for Journal Premium Awards and will normally be published within three months of being received.*

Indicial Admittances for Linear Systems with Variable Coefficients

by

PROFESSOR W. J. DUNCAN, C.B.E., D.Sc., F.R.S., F.R.Ae.S.

(*Department of Aeronautics and Fluid Mechanics, The University, Glasgow*)

THE SOLUTION of a set of m ordinary linear differential equations of the n^{th} order having variable coefficients can be provided by the use of a set of m^2 indicial admittances and the solution is derived from that given by the use of impulsive admittances. The indicial admittances are easily derived from the impulsive admittances and *vice versa*.

INTRODUCTION

An "indicial admittance" is a function representing the response of a system to an applied "input" in the form of a "unit step function" and the concept is due to Heaviside. When the indicial admittance is known, the response to an input which varies with time in an arbitrary manner can easily be found. Similarly, the response can easily be found when the "impulsive admittance" is known, where this is the response to a unit instantaneous impulsive input. The indicial admittance is a concept which is very acceptable to electricians since it represents the response to a unit E.M.F. suddenly switched on but in mechanics the idea of response to a "kick" of unit impulse is particularly clear and obvious. However, the two kinds of admittance are simply related and their uses in the calculation of response correspond to two ways of supposing the area of the graph of input on a base of time to be divided up[1]. When the impulsive admittance is adopted the area is supposed to be divided into narrow strips whose sides are normal to the time axis but when the indicial admittance is used the strips are parallel to the time axis. In this Note the expressions representing the responses in the several degrees of freedom of a system whose differential equations are linear with constant or variable coefficients in terms of a set of indicial admittances are derived from the known expressions in terms of the corresponding set of impulsive admittances[2]. For convenience the special case of constant coefficients is treated first.

LINEAR SYSTEMS WITH CONSTANT COEFFICIENTS

Consider a set of m ordinary linear differential equations of order n in m dependent variables $q_1 \ldots q_m$ and take t as the independent variable. The r^{th} equation of the set, typical of all, can be written concisely

$$\sum_{s=1}^{m} A_{rs}(q_s) = Q_r(t) \quad . \quad . \quad . \quad (1)$$

where $A_{rs}(\quad)$ is an ordinary linear differential operator of the n^{th} order with constant coefficients. Here we have a set of m^2 impulsive admittances $z_{rs}(t-\tau)$ such that a solution of the set is given by

$$q_s(t) = \sum_{p=1}^{m} \int_0^t Q_p(\tau)\, z_{sp}(t-\tau)\, d\tau \quad . \quad . \quad (2)$$

while the initial conditions satisfied by the solution are

$$q_s = \frac{dq_s}{dt} = \ldots\ldots = \frac{d^{n-1}q_s}{dt^{n-1}} = 0. \quad . \quad (3)$$

The admittance function $z_{rs}(t)$ is the expression for q_r in the solution of the set of homogeneous equations obtained from (1) by replacing the functions $Q(t)$ by zero and with the initial conditions

$$z_{rs}(0) = z'_{rs}(0) = \ldots\ldots = z^{n-2}(0) = 0 \quad . \quad (4)$$

$$\sum_{p=1}^{m} a_{rp}\, z_{ps}^{\,n-1}(0) = \delta_{rs} \quad . \quad . \quad . \quad (5)$$

where δ_{rs} is Kronecker's symbol, *i.e.* $\delta_{ss} = 1$, $\delta_{rs} = 0\ (r \neq s)$,

while a_{rp} is the constant coefficient of $\dfrac{d^n q_p}{dt^n}$ in the r^{th} equation of the set (1).

Now let $\beta_{rs}(t)$ be that integral of $z_{rs}(t)$ which vanishes with t, *i.e.* let

$$\beta_{rs}(0) = 0 \quad . \quad . \quad . \quad . \quad (6)$$

while $$\beta'_{rs}(t) = z(t) \quad . \quad . \quad (7)$$

Then we get on integration by parts

$$\int_0^t Q_p(\tau)\, z_{sp}(t-\tau)\, d\tau$$

$$= Q_p(0)\, \beta_{sp}(t) + \int_0^t Q_p'(\tau)\, \beta_{sp}(t-\tau)\, d\tau \quad . \quad (8)$$

Consequently equation (2) becomes

$$q_s(t) = \sum_{p=1}^{m} Q_p(0)\, \beta_{sp}(t) + \sum_{p=1}^{m} \int_0^t Q_p'(\tau)\, \beta_{sp}(t-\tau)\, d\tau \quad (9)$$

The functions β_{rs} are the indicial admittances of the system as can be seen at once from the last equation. Thus, let $Q_r(t)$ have the constant value unity while all the other functions Q vanish. Then equation (10) yields

$$q_s(t) = \beta_{sr}(t), \quad . \quad . \quad . \quad (10)$$

while $q_s(0)$, $q_s'(0)$, $\ldots$ $q_s^{n-1}(0)$ are all zero because of (4) and (7).

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LINEAR SYSTEMS WITH VARIABLE COEFFICIENTS

The set of equations to be solved is still represented by (1) but the linear differential operators now have coefficients which are functions of t. Here[2] the impulsive admittances are functions of the two variables t, τ instead of being functions of the single variable $(t-\tau)$ and the typical admittance is written $\alpha_{rs}(t,\tau)$. The solution corresponding to (2) is

$$q_s(t)=\sum_{p=1}^{m}\int_0^t Q_p(\tau)\,\alpha_{sp}(t,\tau)\,d\tau \qquad . \qquad (11)$$

while the impulsive admittances are defined by the following conditions:

(*a*) $q_k=\alpha_{kl}(t,\tau)$ (l constant) is a solution of the set of homogeneous equations obtained from (1) by substituting zero for $Q_r(t)$.

(*b*) $\alpha_{kl}(\tau,\tau)=0$

$$\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot$$

$$\alpha_{kl}^{\,n-2}(\tau,\tau)=0$$

(*c*) $\sum_{s=1}^{m} a_{rs}(\tau)\,\alpha_{sl}^{\,n-1}(\tau,\tau)=\delta_{rl}$,

where $a_{rs}(\tau)$ is the coefficient of $\dfrac{d^n q_s}{dt^n}$ in the r^{th} equation of the set and the superscript $(n-1)$ indicates repeated partial differentiation with respect to t. The determinant $|a_{rs}(\tau)|$ must not vanish.

Now define the indicial admittance function $\beta_{sp}(t,\tau)$ by the equations

$$\frac{\partial}{\partial\tau}\beta_{sp}(t,\tau)=-\alpha_{sp}(t,\tau) \qquad . \qquad . \qquad (12)$$

$$\beta_{sp}(t,t)=0. \qquad . \qquad . \qquad . \qquad (13)$$

Then $$\int_0^t Q_p(\tau)\,\alpha_{sp}(t,\tau)\,d\tau$$
$$=Q_p(0)\,\beta_{sp}(t,0)+\int_0^t Q_p'(\tau)\,\beta_{sp}(t,\tau)\,d\tau. \qquad (14)$$

Hence, by (11) the solution of the set of equations is expressed by

$$q_s(t)=\sum_{p=1}^{m} Q_p(0)\,\beta_{sp}(t,0)+\sum_{p=1}^{m}\int_0^t Q_p'(\tau)\,\beta_{sp}(t,\tau)\,d\tau. \qquad (15)$$

The initial conditions are again

$$q_s(0)=q_s'(0)=\ \ldots\ .=q_s^{\,n-1}(0)=0. \qquad . \qquad (16)$$

CONCLUSIONS

Any non-singular set of ordinary linear differential equations with constant or variable coefficients can be solved by the use of a set of indicial admittances. These admittances are obtained by integration from the corresponding impulsive admittances which are themselves particular cases of the complementary function of the homogeneous equations of the set. Indicial admittances are rather less simple in use than impulsive admittances for the following reasons:

(*a*) The solution contains additional terms (compare equation (15) with equation (11)).

(*b*) The differential coefficients of the "forcing functions" Q are used instead of the functions themselves.

(*c*) The calculation of the indicial admittances involves an extra step (integration).

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Some Evaporation Measurements on Liquid Sprays

by

W. BERGWERK, Ph.D., D.I.C., B.Sc.(Eng.)

(Now with Marston Excelsior Ltd.; formerly at Imperial College.)

THE EVAPORATION rate of a liquid spray in a turbulent gas stream is of interest in connection with direct contact heat transfer and combustion equipment. Any fundamental approach to this problem has usually dealt with single drops evaporating in an "infinite" atmosphere. The evaporation of sprays from actual atomisers is obviously a more complicated process and few attempts have been made to find in how far single drop data may be applied, or to measure the evaporation from a whole spray.

The main difficulties lie in devising a satisfactory method of measuring the evaporation rate. Selden and Spencer[1], injected the liquid into a bomb filled with hot gas under pressure and measured the decrease in pressure with time on a special indicator. They did not consider that the indicator was sufficiently accurate, however, to give a consistent value for the heat transfer coefficient. Sacks[2] and Hanson[3], sprayed the liquid into an air stream from which samples were taken at various points downstream. This method is only suitable when there is no danger of further evaporation occurring in the collecting apparatus after the sample has been taken. Both authors found wide discrepancies between single drop theory and their results.

A new method is proposed here which uses the pressure drop across a set of orifices passing a known mass flow to give a mean fluid density in the following way.

A steady stream of hot gas is passed through a lagged pipe *ABC* (Fig. 1). The mass flow rate of dry gas is measured at *A* by means of a standard nozzle (BSS. 1042: 1943) and liquid is sprayed into the stream at a point *B*, where the gas temperature is known. Some distance farther downstream is another nozzle *C*, through which passes a mixture of gas, vapour and unevaporated liquid

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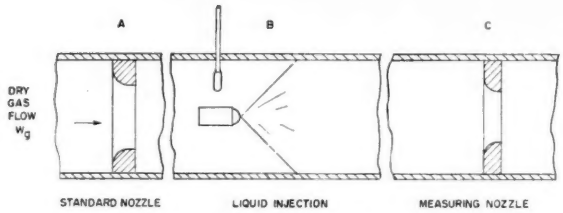

FIGURE 1. Principle of nozzle method.

drops, the time elapsed being calculated from the flow rates. Disregarding for the moment the presence of liquid drops, $W/\sqrt{\rho}$ can be obtained from the pressure drop across C using standard orifice flow formulae.

$$\text{Now} \quad W = W_g(1+x) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where W_g = dry gas flow, lb./sec.

x = lb. of liquid evaporated per lb. dry gas.

If there is no heat loss between B and C, then x and ρ are easily related by appropriate "humidity" charts and the value of x found.

Effects due to the presence of particles in a stream passing through a nozzle have been studied in connection with pulverised coal meters (Carlson, Frazier and Engdahl[4]). It has been found that $W/\sqrt{\rho}$ must be replaced by

$$\frac{\sqrt{W(W+aw)}}{\rho}$$

where w = weight of particles associated with W lb. of gas

a = a factor between 0 and 1, depending upon the shape of the nozzle.

Particle size had only a minor influence.

To allow for the presence of unevaporated water, equation (1) must therefore be amended to read

$$W = W_g(1+x)\left\{1+a\frac{(s-x)}{(1+x)}\right\}^{\frac{1}{2}} \quad . \quad (2)$$

where s is weight of liquid suspended per lb. of gas.

EXPERIMENTS

Some experiments were carried out using this system in a 2·76 in. bore pipe, spraying water into combustion gas at 1175° F. It was found that with a single orifice at C (Fig. 1) the system was rather insensitive but that by placing two orifices in parallel, convenient and sensitive operation could be obtained. One of these orifices (0·279 in. diameter) was arranged to run choked (above the critical pressure ratio) while the other (0·452 in. diameter) was throttled back to hold the upstream pressure at a fixed value. The system was calibrated with cold air, hot combustion gas, and cold saturated air containing a known quantity of suspended water drops. The value of a was found to be 0·67 and there was little scatter among the calibration points except when more than 20 per cent of water by weight was carried through the nozzles. (Fig. 2.)

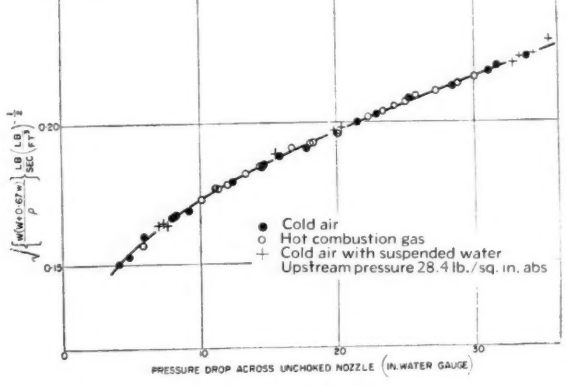

FIGURE 2. Nozzle calibration.

Two swirl atomisers producing known drop sizes were tested at a gas flow rate of about 0·0485 lb./sec. at 28·4 p.s.i.a:

Atomiser	*Cone Angle* degrees	*Flow Number* g.p.h./√(pressure) (in p.s.i.)
A	50	0·98
B	90	0·43

The results are shown in Fig. 3, the "atomiser pressure" referring to the difference between the water and gas pressures.

An attempt was made to check the results obtained by this system with readings of a sheathed thermo-couple. If the thermo-couple were unaffected by the presence of water drops and read the true gas temperature, the average of a temperature traverse taken near the nozzles should be the mixed mean temperature at the required value of x. So long as there was less than about 0·02 lb. of liquid water present per lb. of gas, the temperatures in fact agreed within ±15° F. With greater quantities of water the thermo-couple readings became erratic and finally, with 0·15 lb. water/lb. gas, dropped to the wet bulb temperature.

A considerable amount of water collected on the pipe walls and was drained off and measured. Under some

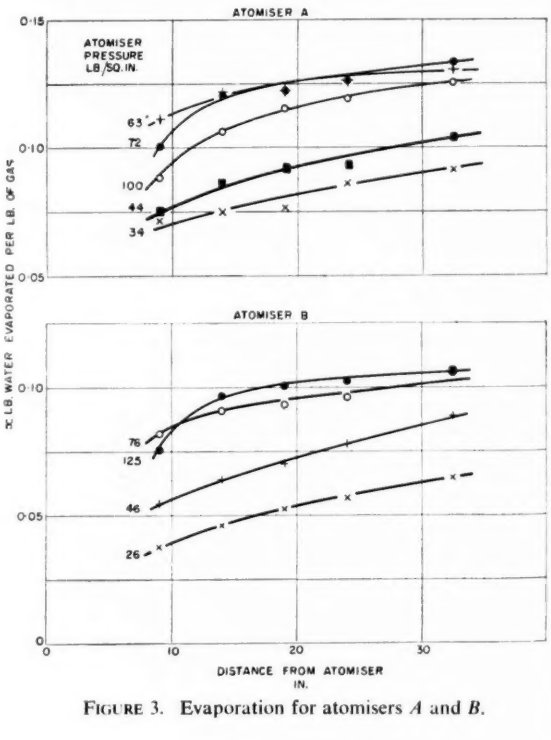

FIGURE 3. Evaporation for atomisers *A* and *B*.

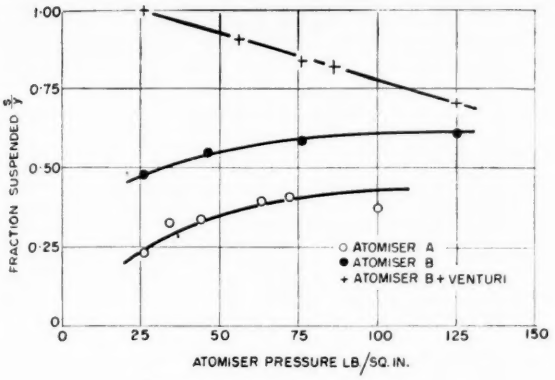

FIGURE 4. Water in suspension.

conditions solid deposits formed on the nozzles and the calibration had to be checked regularly.

RESULTS

The method worked satisfactorily and would appear to be most suited to high evaporation rates. It can only be applied, however, to flow in ducts where the entire mass flow can be metered before and after the liquid is introduced.

More general heat transfer rates are difficult to deduce from the present measurements as a large amount of liquid hit the pipe walls.

Measurements were taken between 9 and 32·5 in. from the atomiser, these limits being fixed by the experimental set-up. The amount drained off was practically independent of the distance from the atomiser and in Fig. 4 the fraction remaining in suspension either as vapour or liquid is shown plotted against atomiser pressure. The wall deposition occurred in the region 0-9 in. where, unfortunately, a major part of the evaporation also took place as seen in Fig. 3. If comparisons with theory are to be made, deposition on the pipe walls introduces two difficulties.

First, the total quantity of spray remaining in the form of drops is reduced and a simple calculation shows that the exposed surface area of a layer of liquid deposited on the pipe wall is usually negligible compared with the surface area of the same quantity of liquid in the form of drops.

Second, the fraction of the spray left in the stream after deposition on the walls has occurred, may have a different drop size distribution from the original spray.

However, to give some idea of the trends observed, a theoretical curve was calculated for the fraction evaporated at 9 in. from the atomiser (Fig. 5), based on the following assumptions:

(*i*) Water drops reach wet bulb temperature before appreciable evaporation takes place (Wentzel[5]). All other temperatures are those actually measured.

(*ii*) Analysis due to Probert[6] for evaporation in infinite atmosphere applies. Drop sizes are those measured in infinite atmosphere.

(*iii*) Heat and mass transfer rates correspond to a limiting Nusselt number of 2.

The graphs show that theoretically the higher pressures and correspondingly smaller drop sizes should give greater evaporation. In this instance, however, the wall deposition also increased so that there was a pressure giving the highest evaporation rate.

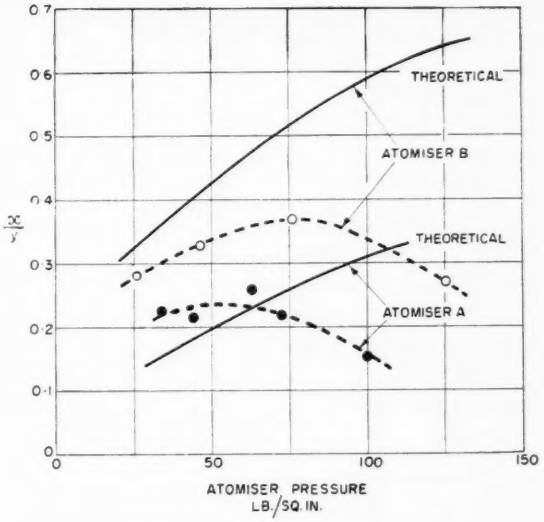

FIGURE 5. Fraction evaporated at 9 in.

As a matter of practical interest a venturi was fitted just downstream of the atomiser in a few experiments so that liquid was sprayed into the convergent part. Both the fraction remaining in suspension and the amount actually evaporated increased appreciably as shown in Figs. 4 and 6.

ACKNOWLEDGMENTS

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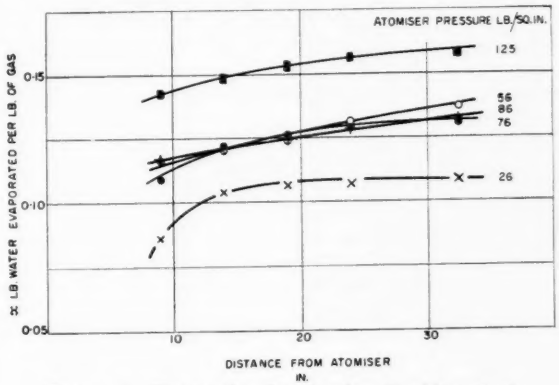

FIGURE 6. Evaporation for atomiser *B* with venturi.

Shock Load Tests of Anti-Vibration Mountings

by

ROLT HAMMOND, A.C.G.I., A.M.I.C.E.

THERE ARE two types of shock loading to which aircraft components are subjected, namely: medium shock loads which can heavily damage equipment; and shocks of high impact, such as those imposed during crash landing, causing the equipment to be torn loose from its mounting, with danger of injury or even death to aircraft personnel.

An impact shock machine has been installed recently in a laboratory for studying this important problem. The machine is capable of providing calibrated shock tests up to a maximum peak acceleration of 77*g*, and of simulating the shock loads normally experienced under everyday operating conditions. Apparatus being tested is mounted on a frame bolted rigidly to the table of the impact testing machine, which has been designed to take specimens up to a maximum weight of 400 lb., with maximum overall dimension equivalent to a cube of 30 inches side. A specimen under test is dropped from a maximum height of 5 ft., falling freely.

One of the main problems of this type of test is that it must obviously be arbitrary, because there is an almost infinite variety of possible shock loads which may be experienced in service, and it would clearly be impossible to represent all field conditions within the confines of a single test. It is claimed that this machine adequately performs its function because it controls test conditions with the necessary limits of accuracy; moreover, the test is so severe that any equipment able to pass it will be rugged enough for practically every type of service.

The machine comprises an elevator platform which moves in a pair of vertical guides located at opposite corners, so that the apparatus under test can be bolted in position without difficulty. The elevator is hoisted and lowered by a wire rope attached to a winch driven by an electric motor of one horse power, operating on three-phase 50-cycle alternating current of 220 volts. The motor is provided with an automatic magnetic brake which ensures rapid and accurate control of drop height. A solenoid operates the release hook of the elevator, a modified bomb release of the " over dead centre " type, in which the weight of the elevator and test specimen tend to lock the hook securely and thereby to make accidental release impossible.

Equipment being tested is subjected to a shock pulse by allowing the table to fall freely into a box of sand which forms the base of the machine. The top of the sand is levelled with a gauge, and the free fall of platform and specimen is abruptly arrested when the level surface of the sand meets a set of wooden impact blocks fixed to the underside of the elevator platform. Severity of shock is easily controlled by varying the height of drop, and the number and arrangement of the impact blocks. The sand in the box is completely non-hygroscopic, and is therefore practically an inelastic material.

When the elevator is sharply stopped at the end of its fall, a single shock pulse without rebound will occur. Both amplitude and duration of shock pulse may be reproduced within the necessary practical limits of accuracy. Recording apparatus comprises a cathode ray oscilloscope with photographic equipment, a time base generator and a filter to eliminate unwanted spurious signals. A set of calibration curves for the particular machine gives peak acceleration of the shock pulse expressed as multiples of the acceleration of gravity, over the range of available drop heights, with four different arrangements of impact blocks. Accuracy of calibration is plus or minus 15 per cent, which is considered to be adequate for practical testing. (Fig. 1.)

To satisfy the requirements of certain military specifications, nominal values of shock duration have been assigned to different arrangements of impact blocks, because these mainly determine the duration of the shock pulse. These values are:—

Duration of Shock Pulse in Milliseconds	*Arrangement of Blocks*
6·5	12
11	10
24	8
32	6

When shock tests are carried out on the mounting bases for airborne electronic components, the ideal method is obviously to test the base with the actual instrument assembly mounted upon it. Often this is not practicable; for example, a component may be in a prototype stage of development, and thus not available for testing, or the mounting base may be intended to be fitted with several instruments of similar size and shape, yet with completely different dynamic properties. However, apart altogether from these difficulties, it may be more economical to use mock-ups because the actual equipment is costly and may be easily damaged during testing.

The ideal test mock-up for a mounting base is one in which weight and moments of inertia are the same about all axes as those of the actual equipment which it simulates. Moreover, it must be fixed to the testing machine in exactly the same manner as would apply to the actual equipment, yet at the same time being interchangeable with the equipment as far as attachment is concerned; in addition, arrangement of mass and elasticity must also resemble that of the actual equipment as closely as possible.

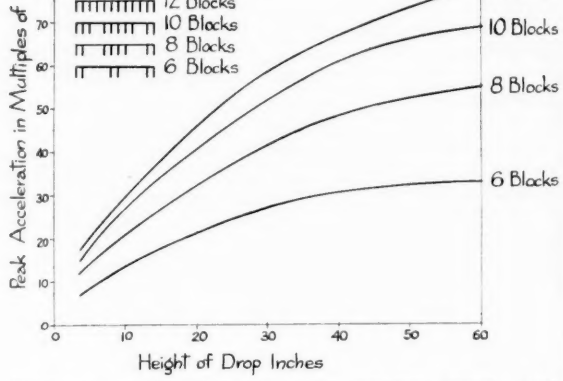

FIGURE 1. Calibration curves for medium impact shock machine.

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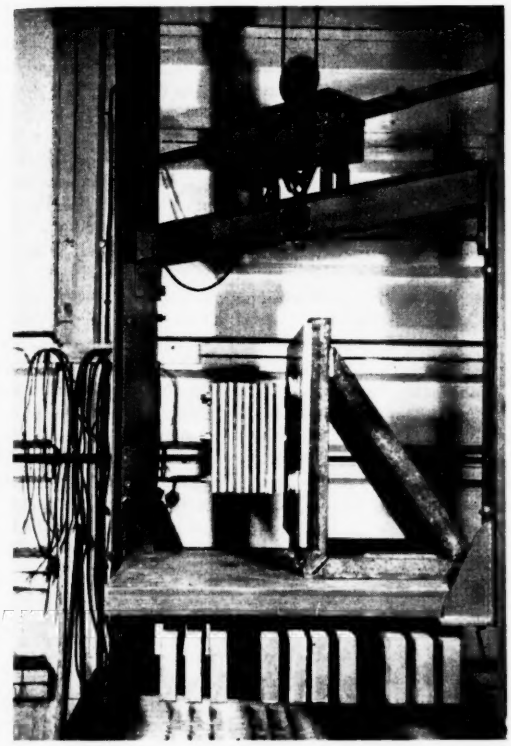

FIGURE 2. Shock testing machine, with mock-up of equipment mounted in the vertical plane. Note impact blocks below the elevator table and quick release gear of the lifting mechanism.

Weight and position of the centre of gravity are generally known accurately, but moments of inertia are neither known nor can they be calculated with much hope of precision. It is therefore standard practice to build a mock-up with a structure of box form, the same general size of the actual equipment but with regular outlines. Weight and position of the centre of gravity are the same as on the original equipment, and it is assumed that density is constant throughout the equipment under test.

In shock testing, a mock-up must be strong enough to withstand the tests, and it should also reinforce the base to the same extent as will occur with the equipment or component being tested. This last requirement is probably the most difficult problem to be solved in designing mock-ups for shock testing. A very important point to bear in mind is that individual components of an equipment do not invariably act together during a shock test.

With electronic apparatus, for example, each individual component is in effect a cantilever beam with a concentrated end load. When the structure to which equipment is attached by anti-vibration shock mountings suddenly acquires high velocity, a damped transient vibration of the equipment as an integral unit is excited at its own natural frequency. This motion of the equipment likewise excites a damped transient vibration of each sub-assembly, also at its own natural frequency.

The many components which make up the whole equipment are thus set vibrating, each at its own natural frequency. If the natural frequency of any component approaches the natural frequency of the equipment upon

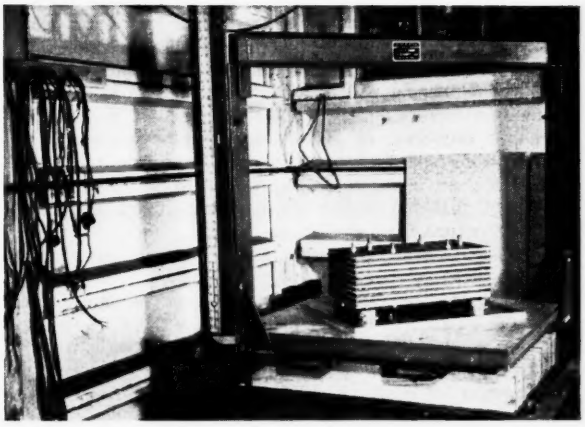

FIGURE 3. Mock-up mounted horizontally on anti-vibration mountings. Elevator table at the end of its fall.

which it is mounted, then resonance will result and the amplitude of vibration of the component may be increased appreciably before vibrations of the equipment and of the component are damped out. Vibration of high amplitude can cause very high stress and may result in failure of the component. Much can be done by the designer of the equipment to reduce possible damage due to shock by ensuring that the components will have a natural frequency at least three times as great as the natural frequency of the mounting system. Exploratory vibration tests on prototype equipment are extremely valuable as an aid to determining whether or not the equipment has adequate stiffness.

Shock tests were recently carried out in the laboratory of Cementation (Muffelite) Ltd., on Barrymount air-damped anti-vibration mountings which have received official approval by the Air Registration Board and are being employed as vibration isolators for much of the electrical and electronic equipment in the Bristol Britannia

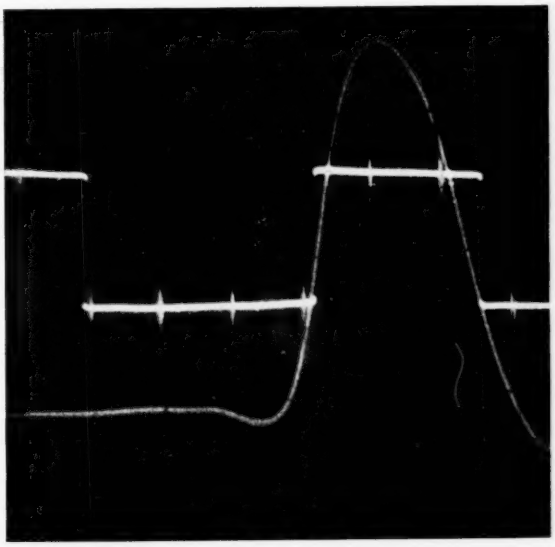

FIGURE 4. Photograph showing 50 c.p.s. calibration trace (square wave) with shock pulse super-imposed.

air liner. In this design of isolator, special care has been devoted to the balloon-type damper bellows, for which either natural rubber or a silicone capable of withstanding very low temperature without loss of elasticity may be used, depending upon temperature requirements in service. Dynamic properties of this isolator have been tested in a low-pressure chamber on a vertical vibrating table, in which the air pressure is equivalent to an operational height of 50,000 ft.; there was only very slight difference in performance from that at sea level.

The load-bearing metal spring has a non-linear characteristic, so that increasing stiffness is provided with increasing load, whereby resonant frequency of the loaded unit will be substantially constant over a range of two to one; moreover, the air-damping bellows absorbs shock loads with a cushioning effect. Operating experience has proved that for peak transient loads of short duration, the air-damping principle will provide adequate cushioning, yet at the same time the absorption and dissipation of resulting oscillations will be improved. In this isolator, the balloon is not the load-bearing member, and therefore variations in its properties will not affect the properties of the isolator short of the melting or crystallisation points. These isolators are generally fitted with balloons and snubbers of cold resistant natural rubber for operation between -40 deg. C. and $+70$ deg. C. Silicones may be employed successfully over even wider ranges of temperature.

The Barrymount isolators tested in the laboratory were selected at random from a production batch of at least 200 units. Each component and assembled isolator was subjected to such visual inspection and/or other tests to comply with normal aircraft inspection procedure; each isolator was also subjected to a standard load-deflection test. Four isolators were then rigidly attached by their normal fixing screws only to a mock-up of such a weight as to load the isolators to their maximum rated load. This mounted unit was then attached to the elevator platform of the testing machine already described, and was subjected to impact shocks each having a peak acceleration of $15g$ and a time duration of 11 milliseconds. Shock loads were then applied vertically and parallel to major and minor horizontal axes respectively, and repeated three times in each case. The unit was then removed from the testing machine and subjected to one or more transmissibility tests, after which it was once more subjected to impact shocks, this time having a peak acceleration of $30g$ and a time duration of 11 milliseconds. Shocks were applied in the directions as described above, except that there were two in each direction instead of three.

Note on a Short-Cut Method for Estimating Aircraft Direct Operating Costs

by

FRANK H. ROBERTSON

(Chief Project Designer, Short Bros. and Harland Ltd.)

IN THE EARLY STAGES of preliminary design, it is essential to have a method for the comparison of aircraft on an operating cost basis. The standard S.B.A.C. method is too lengthy and, in any case, demands a greater amount of data than is usually available in the early design stages.

The formulae presented in this note were evolved by the author some years ago and the general method was quoted in a paper entitled "The helicopter—has it a future?" which was read to the Belfast Branch in January 1955. (*See* Journal, November 1955.)

It is submitted that the formulae give a reasonable first estimate, suitable for early design comparisons, and that the few parameters required are normally available at the earliest stage of the design.

ASSUMPTIONS

1. That direct operating costs other than first cost, insurance, maintenance, repairs, fuel and oil may be treated as negligible.
2. That the life of an aircraft is eight years and that its value after this period is nil.
3. That insurance premiums are approximately 5 per cent of the first cost per annum over the life period.
4. That the first cost of an aircraft is approximately £9 per lb. of the weight of the aircraft less fuel and payload.
5. That the cost of maintenance and repair of an aircraft is approximately £1·25 per lb. of the weight of the aircraft less fuel and payload per year for 1,000 hours annual utilisation and approximately twice that amount for 3,000 hours.
6. That fuel costs approximately 3d. per lb.

NOTATION

W weight of aircraft less fuel and payload in lb.
V true mean cruising speed of aircraft in knots
P payload carried in lb.
F fuel carried in lb.
R equivalent still-air range in nautical miles
N number of passenger seats

FORMULAE

NO. 1. For transport aircraft at 3,000 hours per year utilisation, $\frac{2}{3}$ load factor, total direct operating cost in pence per ton nautical mile =

$$\frac{1{,}000\,W}{VP} + \frac{10{,}000\,F}{PR}$$

and in pence per seat nautical mile =

$$\frac{0{\cdot}45\,W}{VN} + \frac{4{\cdot}5\,F}{NR}$$

Received November 1956.

NO. 2. For transport or executive aircraft at 1,000 hours per year utilisation, $\frac{2}{3}$ load factor, total direct operating cost in pence per ton nautical mile =

$$\frac{2{,}000\,W}{VP} + \frac{10{,}000\,F}{PR}$$

or in pence per seat nautical mile =

$$\frac{W}{VN} + \frac{4{\cdot}5\,F}{NR}$$

NO. 3. For executive aircraft at 150,000 nautical miles per year, $\frac{2}{3}$ load factor, total direct operating cost in pence per seat nautical mile =

$$\frac{0{\cdot}006\,W}{N} + \frac{4{\cdot}5\,F}{NR}$$

(Correspondence on this note will be welcome.—Ed.)

Note on the Bending of a Finite Parallelogrammic Plate under Continuous Non-Normal Loading:—February 1956

Erratum

by

K. I. McKENZIE, B.Sc., Grad.R.Ae.S.

and

M. ROTHMAN, M.Sc., Ph.D., A.F.R.Ae.S.

(The Northern Polytechnic, Holloway, N.7.)

THE FUNCTION given in the Technical Note published in the February 1956 issue of the *Journal*, for the deflection of a parallelogrammic plate simply-supported along two opposite edges, freely hinged along the other two, and subjected to a uniform non-normal load, did not satisfy all the boundary conditions.

The boundary conditions are

$$w=0 \text{ and } \frac{\partial^2 w}{\partial X^2} - 2\cos\alpha\,\frac{\partial^2 w}{\partial X \partial Y} = 0 \text{ on } X=0 \text{ and } X=a$$

$$w=0 \text{ and } \frac{\partial^2 w}{\partial Y^2} - 2\cos\alpha\,\frac{\partial^2 w}{\partial X \partial Y} = 0 \text{ on } Y=0 \text{ and } Y=b \quad . \quad . \quad . \quad (1)$$

where α is the angle of the parallelogram, and X and Y are oblique cartesian co-ordinates measured along the edges of the parallelogram.

The following function

$$w = \sum_{m,n=1}^{\infty} \sum_{\substack{n=1 \\ \text{odd}}}^{\infty} \left(a_{mn} \sin\frac{2m\pi X}{a} \sin\frac{2n\pi Y}{b} + b_{mn} \cos\frac{2m\pi X}{a} \cos\frac{2n\pi Y}{b} \right) \sin\frac{m\pi X}{a} \sin\frac{n\pi Y}{b} \quad . \quad (2)$$

Received December 1956.

does satisfy these conditions, provided that

$$\sum_{\substack{m=1 \\ m\ \text{odd}}}^{\infty} mb_{mn} = \frac{2b}{na\cos\alpha} \sum_{\substack{m=1 \\ m\ \text{odd}}}^{\infty} m^2 \left(a_{mn} + 2a_{\frac{m}{3}\,n} + \ldots + 2\cdot 3^{r-1} a_{\frac{m}{3^r}\,n} \right)$$

$$\sum_{\substack{n=1 \\ n\ \text{odd}}}^{\infty} nb_{mn} = \frac{2a}{mb\cos\alpha} \sum_{\substack{n=1 \\ n\ \text{odd}}}^{\infty} n^2 \left(a_{mn} + 2a_{m\,\frac{n}{3}} + \ldots + 2\cdot 3^{r-1} a_{m\,\frac{n}{3^r}} \right)$$

where $m = 3^r \cdot m'$, $n = 3^r \cdot n'$, and neither of m', n' is a multiple of 3.

The function given by equation (2) can be substituted into the differential equation for the deflection, and provided that each quarter of the plate is treated separately the Fourier expansions for 1, X, Y can be used over the ranges

$$0 \leqslant X \leqslant \frac{a}{2},\ \frac{a}{2} \leqslant X \leqslant a,\ 0 \leqslant Y \leqslant \frac{b}{2},\ \frac{b}{2} \leqslant Y \leqslant b,$$

and a set of simultaneous equations for the a_{mn}'s can be obtained as before.

Graduates' and Students' Section

Hi!

THIS SUMMER I was fortunate enough to obtain a summer scholarship at the Massachusetts Institute of Technology, Boston. Together with 67 other students from 35 different countries I spent a very pleasant four and a half months working on research in our various spheres. I am somewhat diffident about expressing my views on America as a whole after such short acquaintanceship but the Committee insists so here goes!

The flexibility of the American University degree course will be of great interest to graduates and students. The award of a degree is dependent on residence and the gaining of a specified number of "Credit Units" in a number of subjects. These subjects can be chosen from a wide field although certain basic ones, such as mathematics, must be included. Credit Units are gained by attending the course in question and passing the tests during it and the exam. at the end. Most of us will agree that this is the best way of ensuring that we learn as we go and, best of all, it spares us the ordeal of prolonged exams. at the end of each year and the unmentionable horror of "Finals." Furthermore, courses need not necessarily be taken in any specified order and one could easily specialise almost entirely in structures one term and aerodynamics the next. Another advantage of the credit system is that it enables students to transfer from one university to the next in the middle of a degree course without the difficulties attendant on this side of the Atlantic. The quality of instruction at M.I.T. and many other American colleges is first class and in some ways beats British methods in its presentation of fundamentals and the "up-to-dateness" in its applied teaching.

The emphasis on fundamental thinking was one of my most striking impressions. The popular British view is that the Americans don't think deeply before starting a project but instead, rush madly in to build it and suck it and see. As far as I could see nothing could be farther from the truth and in some instances the opposite may be the case. American designers have a deep respect for scientific methods and tend to deplore the popular British "inspired guesstimate." They back this up by providing research facilities both government and private which are far in excess of those in this country. How many readers of this article I wonder have been able over the past five years to call on the use of an analogue or digital computer to help them optimise their design in as exact a scientific manner as possible. Compared with their American colleagues I'm afraid their number would be rather small. I am tempted to think that this type of approach may be partly responsible for the relative performance of American and British aircraft in current service. Of course the very much larger design staffs are responsible for a large part of this difference and the greater number of designers per item of airframe means that greater attention can be paid to individual pieces with better results in the end product. Contrary to some British Aircraft Industry opinion, I did not find American design staff lacking in that divine inspiration with which we are supposed to design "the best aircraft in the world." I would say that Americans and British possess or do not possess this flair in equal quantities. What they do possess however are many more people with equal inspiration to ours, backed by much greater research and production.

It was interesting to note how air-minded the Americans have become. Naturally the large distances to be covered have fostered civil aviation developments but such has been the growth of air travel that people will usually prefer 'plane to train down to distances as low as 120-150 miles. Indeed the railroads have lost so much traffic to the airlines that they are talking about concentrating on freight first class rail travel only. With this popularisation of flying has come a great simplification of ticketing procedures. On one occasion I bought my ticket two minutes before departure and actually boarded the aircraft as they were starting one of the engines.

The wide market for civil aviation has led to the developments which ensure America's predominance in this field today. The large market for all kinds of goods and services enables developments and manufacturing to be carried out on a scale which we, with our smaller market, cannot hope to achieve, unless it be within a European Marketing Community. This in turn leads to the fact that everything from skyscrapers to soda fountains is about one and a half times the size of its European counterpart. Even the food helpings in restaurants are one and a half times as big in quantity but, unfortunately, not in quality.

Coming to the 64 million dollar question "What is one paid?" I can only give the following general figures culled from conversations with the recipients of such salaries. On graduation American aeronautical engineers seem to command between $5000 and $7000 per year. Section leaders range between $7000 and perhaps $12000 depending on ability and responsibility. Above that I didn't dare inquire, although obviously heads of departments and other exalted beings are in the 15-, 20-, 25000 dollar class. What do these salaries mean? Well it seems true to say that a rate of $5 to £1 gives the equivalent absolute purchasing power. Houses, food and services are more expensive than over here but cars, clothes and other consumer goods are about the same price on the direct exchange rate of $2.80.

Finally, to dispel the last remaining myth, almost every American I met was a very pleasant person of friendly disposition and, believe it or not, with a fair amount of self depreciation! He is not the loud mouthed flashily dressed mobster of the film and novel variety. Are there any snags? of course there are. For example the apparent corruption in police, politics and business can only be hinted at, such is its proportions. Of more direct interest the security barriers to be overcome by the foreigner before working in the American aircraft industry mean that a lengthy probation period on menial unclassified jobs must often be gone through. One firm is so discouraged by the slowness of obtaining foreigners' security clearances that it has stopped employing them. And of course the American way of life away from the towns may not suit the more culturally minded Englander.

However be that as it may it's a great country and one which is so large that I could only scrape a very small part of the surface of one particular region during my short stay. Please remember this if your experiences are different from mine.

I hope I will see as many of you as possible at the lectures in the coming session. Particularly I would draw your attention to the N. E. Rowe medals contest on Tuesday 15th January which is a new and most important addition to the Section's Year.

See you around fellers!—P.A.H.

The Annual Dance

THE Section's Annual Dance, held in the Library at 4 Hamilton place on Friday 30th November, was undoubtedly a huge success. Like the Summer Party, tickets for the dance were sold out a week before.

Among those who came to join in the dancing were the President, Mr. E. T. Jones, and his wife, and the Secretary, Dr. A. M. Ballantyne. We were also pleased to see Colin Chapman, Graham Hill, and other representatives of the Lotus Car Company.

Music for dancing, which was provided by Hugh McCanley and his band, was energetically applauded by a very enthusiastic crowd of dancers. Several novelty dances were well received and many valuable prizes were given away. This was probably the first occasion that Rock 'n Roll has been heard at No. 4 but judging by its popularity we doubt if it will be the last.

The bar and buffet were again very popular, so much so that after the interval the bar had to be closed for a while, so as to get the dancing restarted. Red and white wines and Merrydown Cider were supplied at no extra charge, as was the excellent buffet supper.

We must thank members of the committee and Society staff for their relentless efforts, which made the dance such a resounding success. We must also thank the various firms and organisations that lent us model aircraft with which the Society's House was decorated.

We hope that the party planned for the Spring will be as popular, and look forward to seeing all your happy, smiling faces again on this occasion.—A.D.B.

THE LIBRARY

Reviews

THEORY AND PRACTICE OF LUBRICATION FOR ENGINEERS. *D. D. Fuller. Chapman and Hall, London, 1956. 432 pp. Illustrated. 84s.*

This further addition to the rapidly expanding volume of literature on lubrication aims to present the theory to the engineer in a usable and readily assimilated form and to "... systematise and generalise the basic concepts that arise from the theory of lubrication."

The opening chapter on fundamentals of viscosity and fluid flow is followed by one dealing with viscosity and its variables, which describes the various methods of measurement and discusses the effects of temperature, pressure and shear rate on viscosity. Chapters 3 and 4 consider hydrostatic bearings at some length, the latter referring particularly to "squeeze" films in reciprocating bearings.

Hydrodynamic lubrication of plane slider and journal bearings forms the subject matter of the next five chapters, the section ending with a discussion of air lubricated bearings. Chapters 10 and 11 give an account of modern ideas on dry and boundary friction respectively and the book concludes with a useful chapter on bearing materials.

The application of the theory to design problems is illustrated by worked examples in the text and each chapter ends with a list of references.

Much of Chapter 1 is given to deriving the expression for viscous flow through a parallel slot and applying it to the hydrostatic bearings of the Hale telescope ("... the world's largest telescope"). The same theme is pursued in the chapter on hydrostatic lubrication with the addition of further examples but, although compensating orifices are mentioned and illustrated, the engineer receives no guidance on the design of compensating systems.

The section on hydrodynamic lubrication begins with a conventional treatment of plane slider bearings; the solution taking into account side leakage is not included, but effects of side leakage are discussed and tables of factors given. The analysis of full journal bearings starts out in the same way but, after deducing an expression for pressure distribution, the author resorts to numerical methods of integration using arbitrary boundary conditions and the physical significance of the various factors influencing performance is lost. The treatment throughout has clearly aimed at simplicity but, in the effort to achieve this, much important detail has been omitted. A curious desire to avoid a discussion of the full Sommerfeld solution appears to have stood in the way of a more logical development of the subject. With the exception of the chapter on squeeze films the scope of the book is restricted to steady state conditions and problems such as oil film whirl and turbulence receive only a very brief mention.

Practical aspects of bearing design are given considerable attention and much of the material presented will be of interest and value to the engineer; discussion is, however, again confined to plane slider and journal bearings.

The book can hardly be said to fulfil the claims made for it and, in fact, adds little to what has already been said on the subject. Its appeal to students will be restricted by the shortcomings of the theoretical treatment and, although the book contains useful practical information, its range is somewhat limited in the light of modern lubrication problems.—H. NAYLOR.

STRESSES IN AIRCRAFT AND SHELL STRUCTURES. *Paul Kuhn. McGraw-Hill, New York, 1956. 435 pp. Illustrated. 105s.*

Some books afford a general survey of a subject, others go much more into detail. One book is best read at a sitting one long evening in a comfortable armchair; the other is better read at a desk a few pages at a time. From the one the reader should gain a general view, hazy perhaps and indistinct, but nevertheless all of a piece; the other affords no complete grasp of the subject as a whole but offers rather meticulous attention to detail against a background which should be as familiar to the reader as it is to the author.

This latter kind of book is always wide open to criticism, because any reader is likely to find at least some of the detail too fussy, while no reader is likely to have in his mind precisely the same background as the author. The merit of such a book is therefore to be found only by actual use, and no criticism is justified that is not the outcome of prolonged trial. If the book becomes well-thumbed it is good, or at least the best book available. This book certainly will not lack readers, because it really is about stress analysis; and if anyone should imagine that stress analysis is just another name for elasticity, this book will show him how wrong he is.

This is stress analysis in full fig with incomplete diagonal tension, shear lag and cut-outs in the forefront and applications to two and four flange shells both with and without constraint against warping following close behind. Only in diagonal tension is there any consideration of buckling, and even there the effect is represented mainly by empirical relations. On the other hand this development of the theory of incomplete diagonal tension, on the basis of Wagner's theory of the pure state, is most valuable and might indeed have formed the subject of a book on its own. The addition of chapters on shear lag and cut-outs of course extends the value of the work, but it also detracts a little from its merits, because these parts have not the same unquestioned authority. In respect of shear lag in particular, but also of cut-outs and warping, methods of analysis commonly used in this country receive only scant attention.

At the same time the methods described in this book have all been thoroughly tested by experiment, and the experimental results described for the most part justify the analytical methods. The one or two cases of significant disagreement are recorded, and the author is at pains to emphasise that there remains still plenty of room for improvement in this kind of stress analysis.

This book ought to be often consulted, although it is neither a primer of stress analysis nor a complete treatise. It is scarcely suitable for students, but it can scarcely fail to help the practising stressman in his daily work.—H. L. COX.

SOLUTIONS OF PROBLEMS IN AERODYNAMICS. *S. A. Urry. Pitman, London, 1956. 382 pp. Diagrams. 32s. 6d.*

This book is intended mainly for engineering students who are preparing for examinations in aerodynamics, of the standard of the Higher National Certificate. While it does not attempt to deal with the complex potential

function, Degree students, too, would do well to master this clearly written collection of fundamental problems in applied aerodynamics.

The author is to be congratulated on the arrangement of each chapter, namely, a list of essential formulae, followed by about a dozen relevant problems and their worked solutions, selected from the London University Degree examination External B.Sc. Part II, the Royal Aeronautical Society Associate Fellowship examination Part I, and the Institution of Mechanical Engineers Associate Membership Part II. At the end of each chapter about 16-20 similar practice examples, with answers, are supplied. Great care has been taken in labelling equations, and cross-references are meticulously given. Only a few minor misprints have been noticed.

Although the worked solutions develop the standard theory of the listed formulae, the book does not stand by itself as a treatise on aerodynamics, but is intended to supplement lecture notes, and is to be read in parallel with the many standard text books which are available, and which are listed in an excellent bibliography. This book fills a gap that has existed for many years between the out-of-date elementary text books, and the classical text books, which have few numerical solutions and which, consequently, some first class honours engineers still find heavy going!

An Appendix giving standard definitions of aeronautical terms in conformity with the British Standards Institution is a welcome extra. A good list of references is supplied.

The reviewer feels that some of the solutions which include descriptive answers are not full enough for examination purposes. The performance examples are most valuable, but it is felt that those on minimum power and minimum drag are over-done at the expense of other topics. High speed effects on aerofoil characteristics are given very little treatment.

Nevertheless, this is a most useful book for students, lecturers and members of aeronautical technical offices.—D. B. SWINBANKS.

SOLID PROPELLANT ROCKETS. *Alfred J. Zaehringer. American Rocket Co., Michigan, 1955. 162 pp. Illustrated. $4.00. (29s.)*

The author of this book is a B.Sc. He is President of the American Rocket Company—the publishers—and he is Associate Editor of "Jet Propulsion," Rocket Editor of "Ordnance" and Abstractor for "Chemical Abstracts." With such authority one has every reason to expect a book of high quality in every respect. It is therefore most unfortunate that it fails lamentably to come up to such expectations.

In his preface the author says that the book has been "written to provide for a single source of information pertaining to solid propellant rockets . . ." and ". . . should be looked upon as an introduction to the field . . . for the engineer or scientist, although there is much for the intelligent layman."

There is, undoubtedly, a considerable quantity of information that for the first time appears in a single volume. Of its 162 pages nearly two-thirds comprise tables, figures, glossary, illustrations and an excellent collection of some 200 references and bibliography. There remain some 66 pages of descriptive matter covering an introduction and historic survey, interior and exterior ballistics, static and dynamic testing, propellant processing and solid propellant applications.

The value of this work as an introduction to the subject, for any of the categories mentioned by the author, is spoilt by poor presentation and selection of material, by the all too frequent occurrence of loose and inept definition, and by tangled units.

Because of the unfortunate extent of these errors, by no means all are covered in this review.

In Chapter 2 there are three tables giving details of various solid propellants. Table 2.1 gives, among other things, specific impulse, density, ignition and combustion temperatures for nine propellants. Table 2.7 lists the heat of decomposition and maximum theoretical exhaust velocity for fifteen propellants not included in Table 2.1. Table 2.8 gives the chemical composition of nine propellants, five of which also appear in Table 2.1, three in 2.7. In the chapter, two examples are given for the determination of grain details; in neither case is the propellant to be found in the tables.

In the same chapter Table 2.4 is said to give values of γ for "typical combustion gases." Values are given for nine gases at room temperature, and four have no temperatures quoted. Only one gas has a number of values listed in the range 17°C. to 4,000°F.(!) and that is hot air which, to say the least, is an unusual combustion gas from any source.

Throughout the book the terms mass and weight are used as synonyms. Temperatures are freely given in °K, R, F and C, heats of decomposition in K.cal./gm. and of formation in K.cal./mole.

"Thrust or force is proportional to the product of mass and acceleration. The weight of 1 lb. acting on a mass of 1 lb. will impart to the mass (if free to move) an acceleration of 1 gravity. Thus at the surface of the earth under normal conditions a 1 lb. weight acting on another body produces a force of 1 lb."

"Mass ratio $\frac{m_0}{m_1}$ . . . m_0 initial weight in lb."

"Lift is opposite to drag . . . ."

". . . near the velocity of sound the drag nears its maximum value."

"Combustion. A relatively slow oxidation reduction process, usually exothermic and accompanied by the evolution of light."

"The differentiation of the terms rocket artillery, rocket projectiles and rocket missiles is indeed very difficult." "Surface to surface (artillery rockets)." "Fig. 1.1. Typical Artillery Rocket. German R.4M, 5·5 cm. Aircraft Rocket."

And three types of nozzle, Subsonic Nozzle, Supersonic Nozzle and Sonic Nozzle, this last defined as "Velocity of gas at throat is equal to the velocity of sound, velocity of gas at mouth equal to the velocity of sound."

In conclusion, this $4.00 (29s.) book is paper-covered and has been produced using a lithographic process, the pages being photographic reproductions of typed sheets and illustrations. The initial cost of this method is less than normal printing, the saving being considerable on photographs. This may account for the 54 illustrations in this book. While a number of these are very interesting, several add nothing of value to the subject.—D. S. CARTON.

THE LEGAL STATUS OF AIRCRAFT. *J. P. Honig. Martinus Nijhoff, The Hague, 1956. 214 pp. Illustrated. 26s.*

Since, in the course of a single flight, an aircraft can easily traverse successive regions of air space each governed by a different legal system, it might be thought that the universal definition and recognition of the legal status of aircraft would have been one of the first essentials for the orderly growth of commercial air transport.

Unfortunately, this is not so, although the topic is receiving urgent consideration by international lawyers—and is included, for example, in the work of the I.C.A.O. Legal Committee. This book, which was written by the author as a thesis for his Doctorate at Leyden University, is an admirable review of the many problems which arise when attempting to reconcile the highly individual viewpoints of the world's airfaring nations. The principal chapters deal with Sovereignty over the Air Space; Nationality of Aircraft; Rights in Aircraft; Civil Jurisdiction over Aircraft; Criminal Jurisdiction over Aircraft and the Consequences of the Special Legal Status of Aircraft. The text is amply annotated and supplemented by a good bibliography. The complete publication is invaluable as a source-book for the serious student of air law, and will undoubtedly be of assistance to those responsible for drafting acceptable international conventions affecting the legal status of aircraft.

Dr. Honig's comments and opinions will provide material for many lively debates, and it is not easy to choose one single topic for special comment. It may well be that future clarification of the international legal status of aircraft will come not from conventions dealing with orderly or logical divisions of air law—such as the general problem of civil jurisdiction—but rather from conventions dealing with single, very limited objectives—such as the creation and international recognition of valid title to aircraft.

Although the Dutch publishers are to be congratulated on the generally excellent standard of English presentation, future editions would benefit from the correction of a relatively few misprints and occasional errors of language. —H. CAPLAN.

ROYAL NEW ZEALAND AIR FORCE. *The Official History by Squadron Leader J. M. S. Ross. Published in Wellington, New Zealand, by the Department of Internal Affairs, 1955. 343 pp. Illustrated. Price is not quoted.*

I cannot imagine many people approaching the task of reviewing an official war history with great enthusiasm. Certainly I was somewhat reluctant to accept the job and agreed mainly from a sense of duty as a New Zealander who had some considerable knowledge of the birth and growth of this comparatively young Dominion Service, but who, as a member of the R.A.F., could be expected to be sufficiently detached to express unbiased opinions. What finally influenced me was the recollection of a small incident in January 1944, when visiting the Headquarters of Admiral Carney, U.S. Navy, at Noumea. He, with his personal assistant, one Commander Harold Stassen, dropped in for an informal dinner with four New Zealand officers (of different services). When I expressed my surprise at finding New Zealand fighter units taking a very active part in operations under the Admiral's command, he informed me that the R.N.Z.A.F. had provided his best fighter unit. The "tally" he mentioned was most impressive.

This book opens with a concise but nevertheless excellent resumé of aviation in New Zealand before the 1914-18 War. One finds, as often, the enthusiasts and benefactors who, despite lethargy in Government circles, persist until a start is made. Notable for his efforts was the late Sir Henry Wigram, whose name has been perpetuated in that of one of the important airfields. Other names are still honoured in aviation circles, and many hold high executive posts today.

The First World War is not dealt with here. Suffice to say that hundreds of New Zealanders served with distinction in the R.F.C., R.N.A.S. or R.A.F., and one of them, Rhodes-Moorhouse, won the first-ever air V.C. But post-war, despite a recognition by the Government of the importance of air defence, aviation virtually ceased to exist. In 1927, when the reviewer joined as a cadet pilot, there were five permanent officers. Much is owed to these few enthusiasts who persisted, in the face of apathy and opposition, and with vintage aircraft such as Avro Monos, D.H.4's, D.H.9's and Bristol Fighters, in trying to lay solid foundations for what was to become a very effective force.

Much credit should go also to Sir Ralph Cochrane, who in the late thirties as a Group Captain (on loan from the R.A.F.), drew up what is still regarded as a model plan for a Dominion Air Force; but despite this, mobilisation in 1939 found the R.N.Z.A.F. with hardly any operational aircraft and too few trainers.

New Zealand's contribution to the Commonwealth Air Training Plan is dealt with in great detail, and much of this subject matter will be of particular interest to the staff student or historian. The lay reader will be much more interested in the detailed and interesting accounts of operations, to which about two-thirds of the book are devoted. These range from assistance given to the R.A.F. in Malaya in 1941, through a variety of roles under the operational command of the U.S. Navy in the South Pacific, and up to the final surrender of Japan.

Apart from the more stereotyped fighter and bomber operations, the New Zealanders seemed to excel in long range reconnaissance, search and rescue. Many an American airman was picked up from the open sea by New Zealand Catalinas.

On the technical side, their contribution was also greatly valued, particularly in the field of radar, where their detailed knowledge and longer experience of this new weapon was of great value to the Americans.

Their other major contribution was in the air transport field, where they undertook long supply and reinforcing flights, finally developing into the long haul from New Zealand to Japan.

This work is an accurate, well-illustrated and invaluable reference, but additionally the author has succeeded in making much of it attractive and interesting narrative. I certainly found it so.—G. E. WATT.

ENGINEERING DYNAMICS. *Volume II. C. B. Biezeno and R. Grammel. Blackie, London, 1956. 527 pp. Illustrated. 90s.*

The treatise entitled "Technische Dynamik" (1939) by Biezeno and Grammel will be familiar to many readers. For those who have not seen it, the publisher's blurb gives a fair statement of the book's *raison d'être*. It says that:

> "Text books as well as elementary lecture-courses covering the syllabus of Engineering Mechanics have to attach primary importance to simplified, rather academic, problems. For want of space and time, the more difficult problems met in engineering practice are either omitted or cannot be treated as fully as would be required in actual practice. For this reason, most Technical Colleges have instituted special courses in Higher Mechanics dealing with the more complicated problems encountered by the practical designer or research engineer.
>
> "This book is intended to serve a purpose similar to that of these special lectures. It represents a continuation of the usual text-books—a book on 'Engineering Mechanics for Post-Graduates.'"

The authors have thus selected an enormous subject for their book and the result is a monumental work of the first importance.

"Technische Dynamik" was compiled with teutonic thoroughness with the result that it is an enormous tome. The publishers of the English translation have (very rightly) decided to break the book down into four separate volumes. It is the second of these which is under review here and it conforms with the Second Edition (which appeared in 1953) of the original German work.

The title "Engineering Dynamics" is a bit misleading. For "dynamics" is taken to include statics. In fact, Volume II is devoted entirely to statical problems, its sub-title being "Elastic Problems of Single Machine Elements." The volume is divided into four parts covering (*a*) Beams and Shafts, (*b*) Springs and Rings, (*c*) Plates and Shells, and (*d*) Elastic Instability; each part contains a mass of well-organised information.

It would be hopeless to embark on a detailed criticism of an encyclopaedic work such as this in a short review. Moreover, there appears to be little need to make the attempt since the original German text has been in existence for nearly twenty years and has become well established in that period. But it does remain to be said that the translator has done his work well and the publisher has produced a very fine English Edition.—R. E. D. BISHOP.

PROCEEDINGS OF THE SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS. *Volume XIII, No. 2. Edited by C. V. Mahlmann and W. M. Murray. Published by the Society for Experimental Stress Analysis, Cambridge, Massachusetts. 197 pp.*

This volume contains eighteen contributions of which seven are entirely, or in part, concerned with photo-elasticity, and five on the applications of strain gauges. Although none of the contributions are entirely new, few of them will fail to arouse interest in some quarters.

The appearance of an inferred isotropic conducting paper will be welcome news to users of this medium in this country, though the anisotropy of existing papers presents no insurmountable difficulty. The data on water proofing of strain gauges will also be welcomed, though the critical question of drift is entirely overlooked.

The most interesting photoelastic contribution is almost certainly that by Post, who develops the optical analysis of two-dimensional stress problems in a manner which will surely be the last word on the subject for some time to come. The paper by Mesmer places Post's original contribution in historical perspective, and prompts questions on how much is owed to the earlier contributions. The analysis of torsion is also interesting, particularly the letter to the editor. Johnson comes out of the affray with colours flying, and statements in Frocht, Volume 2, are indeed false. The two-dimensional treatment of stresses in a three-dimensional deep arch model is unnecessary and to be regretted.

The conditions under which the thermal stresses can be measured by imposed dislocations is not made clear in the interesting analysis of a steady state temperature distribution. This article deserves, and will no doubt get, very close study with the increasing importance of thermal stresses.

The least satisfactory paper in many ways is the suggestion that a harmonic function can be determined at an internal point by interpolation along a circular arc. This is of doubtful accuracy, though it would certainly be better than linear interpolation. The illogical term "rosette" should not confuse the British reader. It seems to the reviewer that the determination of the tangent to the circular arc by Theocaris is incorrect, and in these circumstances it seems a pity that the proceedings do not carry written discussion.

A general weakness of stress analysts is a preoccupation with the means rather than the ends of the analyses. In particular the results of the biaxial load fatigue tests are given elsewhere. It is difficult to avoid concluding that stress analysts shirk the wider issue of the manner and cause of failure.—C. SNELL.

SUPERSONIC INLET DIFFUSERS AND INTRODUCTION TO INTERNAL AERODYNAMICS. *R. Hermann. Minneapolis Honeywell Co., Toronto. 378 pp. Illustrated. $16.*

Much is heard today of the increasing complexity of aircraft design and of the corresponding increase in specialisation. This book provides a terrifying example. Not long ago, it would hardly have been possible to fill a chapter of a general text with the necessary information for the design of engine air intakes, and now we have a bulky book of 378 pages, which is designed as an introduction to the subject of intake design for the supersonic aircraft, without pretending to cover that limited field completely.

The author, a Professor of Aeronautical Engineering at the University of Minnesota, currently engaged in research work on the subject, on which he has worked since 1937, is a leading authority, and the clear style of his writing reflects his long teaching experience.

The book opens with a general chapter describing the function of the diffuser, outlining the differences between various applications to air intakes and to wind tunnels, and reviewing the basic definitions and equations. Chapters 2 and 3 deal with the simple symmetrical intake (or wind tunnel diffuser) with a throat, the first covering conditions with the shock external, and the process of shock "swallowing," the second covering conditions with the shock swallowed. Chapters 4, 5, 6 and 7 deal with the two-dimensional, multiple inclined shock diffuser, treating in turn the basic theory, the special case of equal wedge angles on the two lips, the Oswatitsch analysis of optimum configuration, and the comparative evaluation of different configurations. Chapters 8 and 9 deal with the axially symmetrical, conical-shock diffuser, the first covering the theory and the second giving a comparison with experimental data. These chapters are confined to the case of one conical shock. Finally there are six pages of tables of useful functions, four pages of references, eight pages summarising all the symbols and terminology used, and a good index running to sixteen pages.

The content, in fact, is rather poorly indicated by the cumbersome title. There is little here that could be used as an "introduction to internal aerodynamics" beyond what is essential to discussion of the supersonic intake in particular. On the other hand, there is much that will be valuable to the designer of supersonic wind tunnels.

The reader is expected to have some basic knowledge of supersonic flow, although the theory is briefly reviewed as required. In general, the mathematics is fairly simple, except in the chapter on the Oswatitsch theory, where the reviewer has to admit that the mathematics went completely underground, as far as he was concerned.

Although information of direct use in application is given, the emphasis is on fundamental understanding, and the great merit of the book is its very clear explanation of various points which are seldom treated so fully. Notable are the description of the shock swallowing process, the lengthy discussion of the differences between

the one-dimensional and the two-dimensional analysis of the symmetrical normal-shock diffuser, the comparison of the flow patterns produced by wedges and cones, and the detailed attention given to the variety of flow patterns set up under different operating conditions of the intake. There is a very useful (if unavoidably inconclusive) section setting out the various theories which have been advanced to explain the "buzzing" instability of conical-shock diffusers, together with a tentative statement of the author's own opinions.

It was noted at the beginning of this review that the book does not set out to cover the whole of the knowledge required in supersonic intake design. In this respect, the most notable feature is the almost complete absence of any discussion of the external effects of the intake and of the appropriate exterior design, subjects of considerable practical importance. Boundary layer effects, and the interaction of shock waves with the boundary layer, are rather sketchily treated, although sufficient qualitative information is given to account for the differences between non-viscous theory and experiment. In relation to the extensive treatment of the normal-shock diffuser and the two-dimensional inclined-shock type, the discussion of the conical-shock diffuser is rather limited, being confined, as already noted, to the case of one conical shock. Some information on more comp'ex types would have been welcome, since this class of intake is of the greatest practical interest. However, this limitation may well be the result of security classification of data.

The binding and general production are of the usual good American quality. The layout of equations is generally clear, with a few exceptions. The typography is, however, perfectly horrible: the letters are badly balanced in design, the "s" in particular being much too heavy, so that a double "s" makes a "black" on the page. The type size is small, but the lines are widely spaced, making for discomfort in reading—all the more regrettable in view of the readability of the style.

Despite these few adverse comments, there can be no doubt that this book should be required reading for all concerned with supersonic intake design, who are bound to find it deepen their understanding. Those concerned with wind tunnel design will also find it valuable.—W. J. D. ANNAND.

HANDBOOK OF METEOROLOGICAL INSTRUMENTS PART I: INSTRUMENTS FOR SURFACE OBSERVATIONS. *Meteorological Office, M.O. 577, H.M.S.O. London, 1956. 458 pp. Illustrated. 45s. 0d.*

For many years *The Meteorological Observer's Handbook*, written by members of the Meteorological Office, London, was the only English text on meteorological instruments, and a very valuable text it was. Knowles Middleton of Canada produced his highly regarded *Meteorological Instruments* in 1941, a second edition appearing in 1943, and gave the subject a somewhat less official and more critical cast. Then in 1952 the Meteorological Office produced a new version of the *Observer's Handbook* in which the information on instruments was kept to the minimum necessary for routine maintenance and simultaneously set its hand to the preparation of a comprehensive text on all instruments used by the Meteorological Office. The volume under review, dealing with surface observations only, is the first result. Further volumes on instruments for the upper air and for geophysical purposes are contemplated.

There are twelve chapters of which three deal with generalities or miscellanea and the other nine are devoted to the measurement of pressure, temperature, humidity, wind, precipitation, evaporation, radiation, visibility and cloud. These mainly follow a pattern of historical introduction, principles of measurement, sources of error, description of instruments, their installation, use and maintenance. Most space is understandably given to those instruments in regular use at official stations—the book is written primarily for their users—but other instruments involving different principles or designed for somewhat different kinds of observations are described and discussed. There is no mention of apparatus for the location of distant thunderstorms by direction finding on atmospherics. No attempt is made here to discuss the book chapter by chapter; a few more or less arbitrarily chosen points are selected instead.

First, two matters of very direct concern to aircraft operation: air-to-ground (slantwise) visibility, and height of base of low cloud. The former subject gets a section of text which points out that the difference between horizontal and air-to-ground visibility is likely to change *in sense* according as the horizontal visibility increases or decreases with height. But no advice is given or instrumentation described whereby the slant visibility can be determined or even estimated. This is not, I think, a criticism of the book but of the need for aircraft operators and meteorologists to decide what they consider should be measured and then to devise the necessary instrumentation. In regard to height of base of cloud, satisfactory methods of measurement (searchlight) are available for use at night, but equally satisfactory day-time techniques do not yet exist in proved form.

Now a more general matter, the errors of observation. The more obvious kinds, *e.g.* lag, are well treated throughout but in more subtle matters the treatment is occasionally inadequate. The measurement of evaporation is an example, where the performance of instruments is well enough described but the relation of their readings to the meteorological quantity desired is only sketchily dealt with. A more critical appraisal of the performance of instruments would similarly be welcome in the measurement of precipitation and in the effect of ventilation on psychrometers.

Here and there, the writing suggests a lack of field experience in using the instruments described or in attempting to measure the variable under discussion. This is perhaps inevitable in such an omnibus volume, but improvement is certainly possible and one may hope that such blemishes will be minimised when, as will certainly occur, a second edition is called for.

All told this is a highly successful publication. It will prove a valuable work of reference not only to professional meteorologists but to the many who are forced to make meteorological measurements to aid other kinds of investigation. It is well illustrated, referenced and indexed and, if not a handsome publication, is at least serviceable. There is no reason why the book should not have its value increased by carrying trade advertisements, but why not print them in an Appendix, make them if possible more representative and avoid the disfigurement which has occurred in the volume as produced?—P. A. SHEPPARD.

AIRCRAFT GAS TURBINES. *C. W. Smith. Wiley, New York. Chapman and Hall, London, 1956. 448 pp. Diagrams. 70s.*

This latest trans-Atlantic contribution to the literature on the aerodynamic and thermodynamic theory of gas turbines is written by a senior member of the General

Electric aircraft gas turbine team, who is also an Adjunct Professor at New York University.

Although this text book does not set out to be a designer's guide, it is nevertheless well worth reading for the clarity of its arrangement and the thoroughness of its treatment of those topics selected for discussion.

An introductory chapter gives a compact descriptive survey of the gas turbine engine, and tidies up such points as what constitutes " normal air " for the present purpose, units and conversion factors, and introduces the convenient symbol X to denote the ever-recurring group $(r^{\frac{\gamma-1}{\gamma}} - 1)$, where r is pressure ratio and γ the ratio of specific heats.

The next chapter deals with some care with the various efficiencies relating to a complete power plant, and contains a helpful discussion on the thrust considered as a pressure integral over the internal surfaces of the engine. Successive chapters then deal with the Brayton cycle and its derivatives, gas dynamics, duct and nozzle flow, intake and exhaust systems, compressors (one chapter on principles common to all, and one each on the centrifugal and axial types), turbines, combustion chambers, dynamic similarity and presentation of test data (two chapters here —perhaps a rather too liberal allowance), controls, stressing and performance and installation. Appendices give numerical data on the aforementioned " isentropic factor " X and other allied quantities, and the volume ends with a quite comprehensive bibliography.

It becomes increasingly difficult to find something new to say about a book of what is now a familiar pattern. Taking a few points at random, one is glad to see some space devoted to methods of thrust augmentation, including reheat, liquid injection to compressor and combustion chamber, and ducted fans. The supersonic compressor receives suitable attention. Potential flow theory of cascades and radial turbines are two topics not often referred to in earlier books.

One must in honesty refer to certain shortcomings, however. The two principal ones are, first, a tendency to over-emphasise the algebraic approach to cycle analysis at the expense of virtually no mention of the essentially arithmetic methods required in practice; and secondly, and more seriously, the entire absence of any diagrams showing typical characteristics of any component whatsoever, nor yet of the engine as a whole. This omission seems almost unbelievable, and of course entails the absence of any worthwhile discussion on off-design performance. It is to be hoped that future editions of this basically sound book will not be allowed to tail off as this does, due to this omission.—J. R. PALMER.

FREQUENCY RESPONSE. *Edited by R. Oldenburger. Macmillan, New York, 1956. 372 pp. Diagrams. 52s. 6d.*

This book, which is dedicated appropriately to Dr. H. Nyquist, consists of the eighteen papers and addresses presented at the 1953 A.S.M.E. frequency response symposium, together with ten additional articles. Each paper is followed by a summary of the discussion arising from it, and the author's closure.

Considering that the contributions come from America, Britain, France, Germany, Japan, the Netherlands and Russia, they cover the frequency response field remarkably well, and with no more duplication than is inevitable in any such collection of individual efforts.

The papers are grouped into nine parts: fundamentals; frequency response aids; servo, aeroplane and power system applications; process control; transient response; optimum controls; non-linear techniques; sampling controls; statistical methods.

The first part includes a useful paper by Oldenburger on frequency response data presentation, standards and design criteria. One needs only to glance through this book to appreciate the need for standardisation in this field, although the task of persuading everyone to agree on a common system may well be formidable—as indeed the discussion following this contribution shows.

The ingenious slide rule devised by Prof. Keisuke Izawa to facilitate gain and phase calculations is fully described in Part 2.

Of particular aeronautical interest is a contribution in Part 3 on experimental flight methods for evaluating frequency response characteristics of aircraft. This deals with the derivation of an analytical transfer function relating aircraft response and control surface movement by analysing the response to a pulse-type control disturbance. This part also includes the description of frequency response tests carried out on the entire Swedish power system.

The problem of determining transient response from frequency response is treated in Part 5; here also appears a paper by Evans on the root-locus method.

Non-linear techniques considered in Part 7 cover contributions to the general theory, as well as the application of frequency response methods to specific types of non-linearity such as saturation and dead band.

It is clear that Dr. Oldenburger, assisted by an eminent panel of reviewers, has put an intense and enthusiastic effort into the editing of this book. The difficulties of the task, involving long-range consultation with contributors in several countries, must have been great, which doubtless helps to explain why the book lags the symposium by something over two years.

Printing, paper and production are excellent and, bearing in mind that the book includes something for everyone from beginner to expert, the price is by no means exorbitant.—S. J. GARVEY.

NUMERICAL ANALYSIS; WITH EMPHASIS ON THE APPLICATION OF NUMERICAL TECHNIQUES TO PROBLEMS OF INFINITESIMAL CALCULUS IN SINGLE VARIABLE. *Zdenek Kopal. Chapman and Hall, London. 1955. 556 pp. 63s.*

The fall of Newton's apple was described in terms of an assumed law, defined at any instant. It could have been described as a set of observations of time and position. The first description is analytical, the second is numerical. They are not only in different languages, but describe different things. They describe different aspects of the same thing if, and only if, the formulator understands the phenomenon more widely and deeply than he has to describe it mathematically. That is, if he is a physicist or engineer, not a mislabelled mathematician.

Even when the analytical representation deals adequately with a particular aspect of the phenomenon—it cannot deal with all aspects, being a description, not a replica—direct translation from analytical to numerical description is not always possible. The symbols and terms of analysis, such as " π," " $\sqrt{2}$," " differentiation," " continuous," are not the names of physically realisable objects or operations. Nor, in general, are physically realisable entities describable in terms of analysis. To use the author's admirable illustration, a seven-figure table of sin x over the first quadrant is a peculiar function with 90,000 discontinuities whose derivatives are alternately zero and non-existent. An infinite-figure table would be even more

awkward, for in analysis a staircase does not become a slope if you make the steps small enough.

Any common footing of these incompatible modes of description lies, as the author shows in his penetrating preface, in algebra. The process of " passage to the limit " is carried out after an algebraic formulation is achieved; in analysis it is carried out before the formulation. The postponed " passage to the limit " can have physical counterparts, such as increasing observational precision or sharpness of description. Then staircases are indistinguishable from slopes if the steps are small enough. (But analytical terms such as " continuity " become meaningless.)

Only the computer-happy will expect the two methods to have the same consequences. In general they do not, especially when the limits of several variables must be approached simultaneously. However, the influence of Newton's, as of an earlier, apple is still strong, and very much scientific computing is concerned with descriptions in terms of derivatives and integrals of functions in a single variable. Here the risks of spurious solutions can be avoided, and reasonably convenient as well as valid methods devised, by a sufficiently skilful and sceptical computor.

To this end Dr. Kopal directs his book. It deals with algebraic methods, not the techniques of calculation. That is, only with those aspects of computing unaffected by the way in which we choose to represent numbers. The book is about strategy not tactics.

The basis is polynomial approximation to a segment of a function of a single variable. Other sometimes more powerful, and currently less convenient, representations such as rotational polynomial fractions are omitted. What remains may be considered adequate, for it fills over five hundred of well-reasoned—and well-printed—pages. Taking off from a form of Weierstrass's Theorem, the author develops polynomial interpolation in terms of values and of differences, and harnesses it to numerical integration of ordinary differential equations. Algebraic and iterative methods for boundary-value problems are examined, followed by a ninety-page study of numerical quadrature. This chapter contains much material, hitherto known to specialists only, that is badly needed in everyday engineering computing. Finally we have methods for integral and integro-differential equations. Five appendices touch on cognate topics, and there are good name and subject indexes. Test problems are set for all chapters but the first.

A most valuable feature is the wealth of bibliographical notes and references. Though not a specialist work, being based on a course of lectures to students, it contains many novel and worthwhile ideas for the professional computor. Also, because it covers domains where lions and lambs are currently maladjusted, there are debatable opinions.

The book is indispensible for any computing unit, and for the individual is a good substitute for the contents of some eighteen inches of shelf space. However, if it is to be applied, or even properly understood, it must be supplemented by skill in the techniques of calculation.

Not the least valuable characteristic is the underlying spirit which raises the mass of data, useful as it is, into a discipline for gaining mastery over the design of numerical weapons.—R. A. FAIRTHORNE.

HISTORY OF THE SECOND WORLD WAR—" ADMINISTRATION OF WAR PRODUCTION." *J. D. Scott and Richard Hughes. H.M.S.O. and Longmans Green, London, 1955. 544 pp. 37s. 6d.*

This book deals with Production Planning and Control of the departments of the Admiralty, the War Office, the Air Ministry, the Ministry of Supply and the Ministry of Aircraft Production. It is a monumental work involving a survey of the constantly varying organisations and administrative arrangements dictated by the development of the war. It contains a short history of the developments which occurred when new Ministers and new central policies of strategy developed in each of these Ministries. No one person, with the possible exception of Sir Winston Churchill, could possibly comment on the whole of this volume; it is clearly a case for four or five separate reviewers, each with personal knowledge of the internal arrangements of each of the Ministries.

Judging from the sections which came within the experience of the reviewer, the condensation and clarification of the mass of available information has been performed with admirable discretion and accuracy. In this respect, the treatment of the Ministry of Aircraft Production is much superior to some of the previous *ex parte* books which have appeared.

To capture the " atmosphere " of those 1940 days is perhaps too much to expect from an historian. Even now, it seems to be a job for an " Alfred Hitchcock " or even an " Edgar Wallace." The facts and their significance have been well appreciated and well presented.

It is perhaps less than generous to point out that consideration of one or two " aircraft programmes " of some importance has been omitted in the condensation. For example, a new programme (subsequent to that of 19th January 1940) was prepared by D.Stats.P. on 13th May 1940 without M.A.P. influence. This was very similar but rose to a peak of 3,000 aircraft as against 2,425 of the January 1940 programme. Although this was not issued to the industry it formed the pattern for many subsequent programmes. In particular it was the basis for the Capacity or " Hennessy " programme of October 1940 which was in fact somewhat lower.

In the intervening period, where there were " five type " and, subsequently, " seventeen type " programmes, these documents were always regarded as *ad hoc* and for short-term action only, to get the types needed on absolute priority, regardless of the fact that the capacity of the whole industry could not thus be harnessed.

There is much in this book which should be " compulsory reading " both to Cabinet Ministers and senior administrators in the Civil Service. It is probably too much to hope that by a study of its contents they will avoid the repetition of the mistakes in the administration of Supply Ministries which seem to have passed along the same strange by-paths in the First and Second World Wars. It will not be the fault of the authors as the right road has been well mapped.

The distaste which departments have for proper detailed planning as opposed to political " planning " are still evident. They arise largely from the " classical " approach of those who are responsible for higher administrative policy, and from the " progmatic " approach of their political masters.—J. V. CONNOLLY.

THE DESIGN OF WING SECTIONS. *T. Nonweiler. Aircraft Engineering. Bunhill Publications, London. 1956. 28 pp. Diagrams. 3s. 6d.*

PERFORMANCE CRITERIA OF GAS-TURBINE COMBUSTION CHAMBERS. *D. B. Spalding. Aircraft Engineering. Bunhill Publications, London. 1956. 37 pp. Diagrams. 4s.*

These are the two most recent booklets in the *Aircraft Engineering* Series of Monographs, and are reprinted from articles which have appeared recently in that Journal.

STABILITY FUNCTIONS FOR STRUCTURAL FRAMEWORKS. *R. K. Livesley and D. B. Chandler. Manchester University Press. 33 pp. Diagrams and Tables. 6s. net.*

The fundamental principles of the Hardy Cross method of moment distribution are unchanged by the inclusion of the effects of axial load, although the stiffness and carry-over factors, however, become dependent upon the axial load. The functions presented in this booklet are intended to be used in this type of approach.

Tables are given of non-dimensional stiffness, carry-over, sway and " No Shear " factors using as the independent variable the ratio of axial load to Euler load. The use of these functions is illustrated by a number of worked examples.—A. J. B.

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820 Propellers for high speed aircraft. D. H. Jacobson.
821 Electric equipment problems in supersonic vehicles. V. B. Hart.
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652 Applications of ultrasonics in aircraft. C. P. Albertson and P. Melara.
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654 A survey of the advantages of transistors in airborne electronic equipment. E. F. Johnson
655 The airport and airways surveillance radar for Canadian air traffic control. B. I. McCaffrey.
656 A method for evaluating jet-propulsion-system components in terms of missile performance. R. W. Luidens and R. J. Weber.
657 The technology of guided missiles and its effect on industry. R. D. Richmond and J. F. Perrier.
658 R.C.A.F. test and development. O. B. Philp.

Reports

AERODYNAMICS

Boundary Layer

Characteristics of turbulence in a boundary layer with zero pressure gradient. P. S. Klebanoff. N.A.C.A. Report 1247. (1955).

The results of an experimental investigation of a turbulent boundary layer with zero pressure gradient are presented. Measurements with the hot-wire anemometer were made of turbulent energy and turbulent shear stress, probability density and flattening factor of u-fluctuation, spectra of turbulent energy and shear stress, and turbulent dissipation. —(1.1.3.1).

Turbulent shear spectra and local isotropy in the low-speed boundary layer. V. A. Sandborn and W. H. Braun. N.A.C.A. T.N. 3761. (*September* 1956).

From measurements of turbulent shear spectra together with previously reported longitudinal turbulent energy spectra, the concept of local isotropy in a low-speed boundary layer was examined.—(1.1.3.1).

Compressible Flow—*see also* Wings and Aerofoils

Axially symmetric shapes with minimum wave drag. M. A. Heaslet and F. B. Fuller. N.A.C.A. Report 1256. (1956).

Optimum bodies consisting of a basic cylinder with added peripheral volume are derived and presented in terms of the effective radius-length ratio. Variation of this parameter from 0 to ∞ encompasses the spectrum of results from slender to two-dimensional. A reciprocal theorem leads to simple interpretation of variational problems.—(1.2.3.1).

The near noise field of static jets and some model studies of devices for noise reduction. L. W. Lassiter and H. H. Hubbard. N.A.C.A. Report 1261. (1956).

Experimental studies of the pressure fluctuations near jets were made during unchoked operation of both a full-scale turbo-jet engine and a 1-inch-diameter high-temperature model jet and during choked operation of model jets of 0·275-inch to 2·00-inch diameter with unheated air. Frequency spectra and spatial distributions of pressure magnitude are given for the full-scale configuration and model data are used to illustrate probable trends at different operating conditions for the unchoked jets.—(1.2).

Aerodynamic investigation of a parabolic body of revolution at Mach number of 1·92 *and some effects of an annular supersonic jet exhausting from the base. E. S. Love. N.A.C.A. T.N.* 3709. (*September* 1956).

An aerodynamic investigation of a slender pointed parabolic body of revolution was conducted at a Mach number of 1·92 with and without the effects of an annular supersonic jet exhausting from the base. Measurements with the jet inoperative were made of lift, drag, pitching moment, base pressures, and radial and axial pressures. With the jet in operation, pressure measurements were made over the rear of the body with the primary variables being angle of attack, ratio of jet velocity to stream velocity, and ratio of pressure at jet exit to stream pressure.—(1.2.3).

General theory of wave-drag reduction for combinations employing quasi-cylindrical bodies with an application to swept-wing and body combinations. J. N. Nielsen and W. C. Pitts. N.A.C.A. T.N. 3722. (*September* 1956).

An analysis is made of wave-drag reduction for wing and quasi-cylindrical body combinations produced by changes in cross-sectional shape and in area distribution. The theory, applicable at all supersonic speeds, has been applied to a swept wing and body. An analytical expression for the optimum axially symmetric indentation is obtained by an alternate method.—(1.2.3.1).

Supersonic flow past nonlifting bumped and indented bodies of revolution. F. E. McLean and C. Rennemann. N.A.C.A. T.N. 3744. (*September* 1956).

Linear-theory values of the supersonic pressure field and wave drag of non-lifting bumped and indented bodies of revolution are presented and compared with the corresponding properties of a smooth body.—(1.2.3.1).

The use of perforated inlets for efficient supersonic diffusion. J. C. Evvard and J. W. Blakey. N.A.C.A. T.N. 3767. (*September* 1956).

The use of wall perforations on supersonic diffusers to avoid the internal contraction-ratio limitation is described. Experimental results at a Mach number of 1·85 on a preliminary model of a perforated diffuser having a geometric internal contraction ratio of 1·49 (the isentropic value) are presented. A theoretical discussion of the flow coefficients as well as the size and the spacing of the perforations is also included.—(1.2.3).

Stability derivatives of cones at supersonic speeds. M. Tobak and W. R. Wehrend. N.A.C.A. T.N. 3788. (*September* 1956).

The aerodynamic stability derivatives due to pitching velocity and vertical acceleration are derived for circular cones travelling at supersonic speeds. Both first-order and a combination of first- and second-order potential solutions are obtained, and, in calculations for the forces, no approximations are made to the tangency condition or the isentropic pressure relation. In addition, expressions for the forces, moments, and stability derivatives of arbitrary bodies of revolution are derived from Newtonian impact theory.—(1.2.3.1 × 1.8.2.2).

Control Surfaces—*see also* Wings and Aerofoils

*Control effectiveness tests at transonic speeds on an EC.*1250 *section with* 0·25 *chord concave control. T. Lawrence. R. & M.* 2809. (1955).

Control effectiveness tests, using the ground-launched rocket-boosted model techniques, have been made on rectangular wings of aspect ratio 4, EC.1250 section, and fitted with a 25 per cent chord concave control flap. Tests were done from $M = 0{\cdot}73$ to $M = 1{\cdot}5$, and at $R = 3{\cdot}5 \times 10^6$ and 7×10^6 at $M = 1$.—(1.3 × 25·2).

Exploratory investigation of the effectiveness of biplane wings with large-chord double slotted flaps in redirecting a propeller slipstream downward for vertical take-off. R. H. Kirby. N.A.C.A. T.N. 3800. (*October* 1956).

Results are presented from static-force tests on biplane wings with large-chord double slotted flaps which turn the slipstream of a single counter-rotating propeller downward for vertical take-off. The investigation provided information on the effect of chord length, flap deflection, propeller position, end plates, fuselage, and ground proximity on the efficiency of the wing system in turning the propeller slipstream.—(1.3.4 × 1.10.2.2).

Internal Flow

Tests on a single-stage turbine comparing the performance of twisted with untwisted rotor blades. I. H. Johnston and L. R. Knight. R. & M. 2927. (1956).

An experimental single-stage turbine designed for the testing of a variety of blade forms with cold air is described together with the instrumentation provided for test measurements.—(1.5.3).

Loads

Initial results of a flight investigation of the wing and tail loads on an airplane equipped with a vane-controlled gust-alleviation system. T. V. Cooney and R. L. Schott. N.A.C.A. T.N. 3746. (*September* 1956).

Results are given of an analysis of wing and horizontal-tail spar strains measured on a twin-engined light transport aeroplane which was modified for the installation of a control system to alleviate aeroplane motions in turbulent air and thus improve passenger comfort. Measurements of aerodynamic loads obtained in a pull-up with the gust-alleviation system in operation are also presented.—(1.6.3).

NOTE.—*The figures in parenthesis at the end of each Summary are for office use only.*

Calculation of the forces and moments on a slender fuselage and vertical fin penetrating lateral gusts. J. M. Eggleston. N.A.C.A. T.N. 3805. (*October* 1956).

A theory is presented for calculating the variation with frequency of the lateral-force and yawing-moment coefficients due to sinusoidal side gusts passing over the profile of a simple fuselage—vertical-fin combination. The analysis is based on slender-body theory.—(1.6.3).

STABILITY AND CONTROL—*see* COMPRESSIBLE FLOW AND TESTING INSTRUMENTS—MISSILES

THERMO-AERODYNAMICS—*see* STRUCTURES—WEIGHT ANALYSIS AND CONTROL

WINGS AND AEROFOILS—*see also* CONTROL SURFACES

Theory of aerofoil spoilers. L. C. Woods. R. & M. 2969. (1956).

A mathematical theory of aerofoil spoilers in two-dimensional subsonic flow is presented. Equations are given for load distributions, lift, drag, moments and hinge moments produced by spoiler-flap combinations. The theory is developed for a spoiler in a general position but the trailing-edge spoiler receives special attention.—(1.10.1.1 × 1.3).

Finite span wings in compressible flow. E. A. Krasilshchikova. N.A.C.A. T.M. 1383. (*September* 1956).

Equations are developed using the source distribution method for the velocity potential function and pressure on thin wings in steady and unsteady motion. Closed form solutions are given for harmonically oscillating wings of general plan form including the effect of the wing wake. Some useful examples are presented in an appendix for arrow, semi-elliptical, and hexagonal plan form wings.—(1.10.1.2 × 1.2.3.1).

The results of wind-tunnel tests to a Mach number of 0·90 *of a four-engine propeller-driven airplane configuration having a wing with* 40° *of sweepback and an aspect ratio of* 10. *G. G. Edwards et al. N.A.C.A. T.N.* 3789. (*September* 1956).

The effects of operating propellers on the longitudinal characteristics of the model have been investigated at thrust coefficients up to 0·9 per propeller at Mach numbers from 0·082 to 0·90 and at Reynolds numbers from 1,000,000 to 8,000,000. Variations in the model included different heights and incidences of the horizontal tail, split flaps, several propeller-blade angles, and independent as well as simultaneous operation of the inboard and outboard propellers. Coefficients of lift, longitudinal force, pitching moment, propeller thrust, and propeller power are presented.—(1.10.2.2 × 1.12.1.1).

Analysis of wind-tunnel tests to a Mach number of 0·90 *of a four-engine propeller-driven airplane configuration having a wing with* 40° *of sweepback and an aspect ratio of* 10. *G. G. Edwards et al. N.A.C.A. T.N.* 3790. (*September* 1956).

Experimental data published in N.A.C.A. T.N. 3789 are analysed. The effects of operating propellers on the longitudinal characteristics of the model are separated into various components to illustrate the origin, nature, and intensity of each.—(1.10.2.2 × 1.12.1.1).

HELICOPTER AERODYNAMICS

Studies of the speed stability of a tandem helicopter in forward flight. R. J. Tapscott and K. B. Amer. N.A.C.A. Report 1260. (1956).

Analytical and experimental studies and corresponding pilots' opinions of the speed stability of a tandem helicopter are presented and means for improving the speed stability are discussed. An analytical expression is derived for use in predicting changes in speed stability of a tandem helicopter brought about by changes in the rotor geometry. Constants for use with the analytical expression are presented in chart form.—(1.11.2).

A theoretical estimate of the effects of compressibility on the performance of a helicopter rotor in various flight conditions. A. Gessow and A. D. Crim. N.A.C.A. T.N. 3798. (*October* 1956).

The effects of compressibility arising from high-tip-speed operation on the flapping, thrust, and power of a helicopter rotor in forward speed are investigated for a particular set of aerofoil characteristics. Tip-speed ratios ranging from 0·2 to 0·5 were covered at several tip-speed values.—(1.11.3).

TESTING AND INSTRUMENTS—*see also* WINGS AND AEROFOILS

Calibration of the flow in the working section of the 3 *ft.* × 3 *ft. tunnel, National Aeronautical Establishment. D. E. Morris. C.P.* 261. (1956).

A number of calibrations, consisting of both Pitot and static pressure measurements and also flow direction measurements, have been made of the flow in the working section of the 3 ft. × 3 ft. supersonic tunnel. Some selected examples are given to show the general nature of the flow distribution with the $M = 1{\cdot}4$, 1·6, 1·8 and 2·0 nozzles and to demonstrate a number of interesting points in the measurements and in the characteristics of the flow.—(1.12.1.3).

Flow direction measurements in supersonic wind tunnels. D. J. Raney. C.P. 262. (1956).

Some general requirements for satisfactory flow direction measurements in supersonic tunnels are stated and examples are given of the design and calibrations of typical yaw-meters. The results of flow direction measurements made in two tunnels are given and some of the flow characteristics are discussed.—(1.12.1.3).

*Note on the Nilson method of variable supersonic wind tunnel design. M. M. Callan. N.A.E. LR-*174. (*May* 1956).

The Nilson method of nozzle design is discussed and extended, and from results obtained in calculations based on the method, certain tests for the basic function used in the development are suggested.—(1.12.1.3).

Condensation effects and air drying systems for supersonic wind tunnels. J. J. Smolderen. AGARDograph 17. (*July* 1956).

A study of condensation effects and a criterion is presented for the complete removal of these effects. Conditions under which disturbances are sufficiently small are also indicated. The second part studies drying processes in use and the third part surveys measuring devices for the determination of humidity.—(1.12.1.3).

Wind tunnel models. R. P. Davie. AGARD. Report 19. (*August* 1956).

This paper deals with wind tunnel models, their design, and construction. It is based on experience gained by the Model Design Group of North American Aviation, Inc., Los Angeles Division, as observed by the author and his associates. Only unclassified material is included.—(1.12).

A wind-tunnel test technique for measuring the dynamic rotary stability derivatives at subsonic and supersonic speeds. B. H. Beam. N.A.C.A. Report 1258. (1956).

An experimental technique for measuring dynamic stability derivatives of a model aeroplane in a wind tunnel is described. A single-degree-of- freedom, feedback-controlled, forced-oscillation system was used to measure the stability derivatives which are important in estimating the lateral and longitudinal oscillatory motions of a rigid aeroplane. Some representative experimental data is included.—(1.12.1 × 1.8).

Transition-flight tests of a model of a low-wing transport vertical-take-off airplane with tilting wing and propellers. P. M. Lovell and L. P. Parlett. N.A.C.A. T.N. 3745. (*September* 1956).

An investigation of the stability and control of a low-wing four-engined transport vertical-take-off aeroplane during the transition from hovering to normal forward flight has been conducted with a remotely controlled free-flight model. The model had four propellers distributed along the wing with the thrust axes in the wing-chord

plane. The wing could be rotated to 90° incidence so that the propeller thrust axes were vertical for hovering flight.—(1.12.1.2).

Wind-tunnel calibration of a combined pitot-static and vane-type flow-angularity indicator at Mach numbers of 1·61 *and* 2·01. *A. R. Sinclair and W. D. Mace. N.A.C.A. T.N.* 3808. (*October* 1956).

A limited calibration of a combined Pitot-static tube and vane-type flow-angularity indicator has been made in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1·61 and 2·01.—(1.12.5).

AEROELASTICITY

See also STRUCTURES—LOADS

Aerodynamic derivatives for two cropped delta wings and one arrowhead wing oscillating in distortion modes. D. L. Woodcock. C.P. 268. (1956).

Aerodynamic derivatives are given for three particular plan forms oscillating with symmetric distortion modes in incompressible flow.—(2).

DESIGN AND CONSTRUCTION

Tests to determine the adhesive power of passenger-car tires. B. Förster. N.A.C.A. T.M. 1416. (*August* 1956).

Experimental data on braking coefficients of friction and cornering characteristics for automobile tyres are presented. The data serves to indicate certain basic aspects of the tyre behaviour and should be of interest to those concerned with the study of tyre braking and cornering characteristics.—(4.2.2.3).

Band-pass shock and vibration absorbers for application to aircraft landing gear. E. Schnitzer. N.A.C.A. T.N. 3803. (*October* 1956).

To overcome rigidity limitations of conventional shock absorbers over certain frequency ranges or rates of load application, frequency-discriminating band-pass shock absorbers are introduced and the principles of operation are explained. The application of a low-pass shock strut to high-speed aircraft for which conventional oleo struts become rigid links when loads are rapidly applied during landing or taxying over steep bumps is discussed. Theoretical solutions indicate marked load reductions for the low-pass shock absorbers for steep bumps or water waves and equal actions of both struts for long hills or swells. Possible extension of the principles to double-action band-pass vibration absorbers is discussed.—(4.2.2.3).

FLIGHT TESTING

The quantitative evaluation of an aircraft control system. R. R. Duddy. AGARD. Report 29. (*February* 1956).

This report is an introduction to the problem of making a quantitative assessment of the ability of an aircraft-pilot system to perform a given task. Two examples are given to illustrate the inadequacy of simple measurements of the accuracy with which a task can be performed.—(13).

Flight techniques for determining airplane drag at high Mach numbers. De E. Beeler et al. N.A.C.A. T.N. 3821. (*August* 1956).

The accelerometer method for the flight measurement of total aeroplane drag during research investigations of high-speed aeroplanes requires special instrumentation and measuring techniques which are described in detail. Methods for separating the flight-measured overall drag into drag components and for comparing the flight data with wind tunnel model data are presented.—(13.3).

MATERIALS

Tensile properties of AZ31A-0 magnesium-alloy sheet under rapid-heating and constant-temperature conditions. I. M. Kurg. N.A.C.A. T.N. 3752. (*August* 1956).

Specimens of AZ31A-0 sheets were heated to rupture at nominal rates of 0·2°F. to 100°F. per second under constant tensile load conditions. The data are compared with the results of conventional tensile stress-strain tests at elevated temperatures after ½-hour exposure. A temperature-rate parameter was used to construct master curves from which stresses and temperatures for yield and rupture can be predicted under rapid-heating conditions. A comparison of AZ31A-0 and HK31XA-H24 is included.—(21.2.2).

Some observations on the relationship between fatigue and internal friction. S. R. Valluri. N.A.C.A. T.N. 3755. (*September* 1956).

Results are presented of an investigation made to determine the internal friction and fatigue strength of commercially pure 1100 aluminium under repeated torsion at various temperatures and stress levels in an effort to find if there exists any correlation between internal friction and fatigue characteristics.—(21.2.2 × 31.2.2.3.2.2).

MATHEMATICS

On a method for optimization of time-varying linear systems with nonstationary inputs. M. Shinbrot. N.A.C.A. T.N. 3791. (*September* 1956).

By means of examples, a new method is illustrated for optimising, over a finite interval of time, time-varying systems with stationary or non-stationary statistical inputs. The method depends on the correlation functions being of a certain type, which, fortunately, is the type found in a large number of practical problems of importance.—(22 × 25.1).

MECHANICAL ENGINEERING

Effect of three design parameters on the operating characteristics of 75-millimeter-bore cylindrical roller bearing at high speeds. W. J. Anderson. N.A.C.A. T.N. 3772. (*October* 1956).

A total of 30 bearings were run at loads to 368 lb. and DN values to 2.1×10^6. The effects of roller axial clearance ratio, cage diametral clearance ratio and cage land width-diameter ratio were investigated.—(23.1).

MISSILES

See also AERODYNAMICS—CONTROL SURFACES AND MATHEMATICS

Generalized trajectory curves for bodies moving in air. R. J. Templin and M. M. Callan. N.A.E. Note 13. (1956).

A chart has been constructed which enables rapid development, using a step method, of trajectory curves having any initial values of the ratio initial velocity to terminal velocity, and the angle of the trajectory to the horizontal. The ratio V/V_t is used as a variable to extend the usefulness of any one trajectory which is developed.—(25.2).

Flight investigation of the performance of a two-stage solid-propellant Nike-Deacon (Dan) meteorological sounding rocket. R. H. Heitkotter. N.A.C.A. T.N. 3739. (*July* 1956).

A flight investigation of two Nike-Deacon (DAN) two-stage solid-propellant rocket vehicles indicated satisfactory performance may be expected from the DAN meteorological sounding rocket.—(25.1.3).

An optimum switching criterion for third-order contactor acceleration control system. A. L. Passera and R. G. Willoh. N.A.C.A. T.N. 3743. (*August* 1956).

A switching criterion for optimum performance of a third-order contactor acceleration control system having complex roots is presented. Analytical and analogue computer methods are utilised to determine this criterion. The resulting optimum transient responses are presented and compared with those of an equivalent linear system.—(25.1 × 1.8.2).

POWER PLANTS

Near noise field of a jet-engine exhaust. II-*Cross correlation of sound pressures. E. E. Callaghan et al. N.A.C.A. T.N.* 3764. (*September* 1956).

Pressure cross correlations were obtained over a range of jet velocities both longitudinally and laterally for the overall sound pressure and for several frequency bands. The results are interpreted in terms of pressure loads on surfaces.—(27.1).

The design of brittle-material blade roots based on theory and rupture tests of plastic models. A. J. Meyer et al. N.A.C.A. T.N. 3773. (*September* 1956).

Theoretical design charts based on Neuber's equations for symmetrically located notches are presented for estimating the approximate rupture strengths of blade roots made from brittle materials. The limit of applicability of the charts is shown as determined by rupture tests of plastic models. The optimum proportions among overall root width, neck width, notch radius, and notch depth are determined. Eighteen different root designs were investigated, their relative strengths were evaluated analytically and experimentally, and the results were compared.—(27).

Further investigation of the feasibility of the freeze-casting method for forming full-size infiltrated titanium carbide turbine blades. E. M. Grala. N.A.C.A. T.N. 3769. (*October* 1956).

A method of casting a full-size cermet turbine blade from titanium carbide was investigated. An extremely thick slip of titanium carbide was prepared with a small amount of binder, cast into a mould by vibration, centrifuged, and frozen to retain the shape of the mould. The casting was then dried in an absorbent sand and sintered by conventional means. The porous casting could then be infiltrated with a nickel- or cobalt-base alloy.—(27 × 28).

Experimental investigation of a lightweight rocket chamber. J. E. Dalgleish and A. O. Tischler. N.A.C.A. T.N. 3827. (*October* 1956).

Experiments have been conducted with a jacketed rocket combustion chamber that was fabricated by hydraulic forming from sheet metal.—(27.3).

PRODUCTION ENGINEERING

See POWER PLANTS

FATIGUE

See STRUCTURES—THEORY AND ANALYSIS AND TESTING

SCIENCE—GENERAL

See also THERMODYNAMICS

Contribution a l'étude de la combustion des bases pyridiques. J. Ploquin. Pub. Sc. et Tech. N.T. 69. (1956).

La combustion lente des bases pyridiques s'effectue entre 400° et 600°C. avec formation primaire d'oxyde de carbone puis d'anhydride carbonique et dégagement d'azote moléculaire. Les homologues de la pyridine brûlent plus aisément que la pyridine elle-même; seule celle-ci peut présenter un pouvoir antidétonant.—(32.1 × 34.1.1).

Tentative method for calculation of the sound field about a source over ground considering diffraction and scattering into shadow zones. D. C. Pridmore-Brown and U. Ingard. N.A.C.A. T.N. 3779. (*September* 1956).

A semi-empirical method is given for the calculation of the sound field about a source over ground considering the effects of vertical temperature and wind gradients as well as scattering of sound by turbulence into shadow zones.—(32.2.3).

STRUCTURES

LOADS

The influence of rope stretch on tension variations in arresting gears. N. I. Bullen. R. & M. 2964. (1956).

When considering the performance of an arresting gear as a whole, it is usual to assume an inextensible rope which automatically excludes the possibility of developing oscillations in the predicted tensions. A method of calculation is given which removes this limitation. The calculations are made for a constant-pressure type arresting gear and the tension oscillations are shown to be interrelated with the action of the constant-pressure valve and the general hydraulic system. The results are compared with actual values obtained from such a gear. The calculations are repeated for an inextensible rope with the same gear.—(33.1.2).

An experimental study of applied ground loads in landing. B. Milwitzky et al. N.A.C.A. Report 1248. (1955).

A study is made of the applied ground loads and the coefficient of friction during wheel spin-up in impacts of a small landing gear under controlled conditions. The basic investigation included impacts with forward speed, impacts with forward speed and reverse wheel rotation to simulate higher horizontal velocities, and spin-up drop tests. The effects of wheel pre-rotation to reduce the relative horizontal velocity were also investigated.—(33.1.2).

Comparison of several methods for obtaining the time response of linear systems to either a unit impulse or arbitrary input from frequency-response data. J. J. Donegan and C. R. Huss. N.A.C.A. T.N. 3701. (*July* 1956).

Several methods of obtaining the time response of linear systems to either a unit impulse or an arbitrary input from frequency-response data are described and compared. Some discussion is given of the use of the methods as flight-data-analysis techniques in predicting loads and motions for a flexible aircraft when the aircraft frequency response is known.—(33.1.2 × 2).

THEORY AND ANALYSIS

The buckling shear stress of simply-supported, infinitely-long plates with transverse stiffeners. P. W. Kleeman. R. & M. 2971. (1956).

This report is an extension of previous theoretical investigations of the elastic buckling in shear of flat plates reinforced by transverse stiffeners. The plates are treated as infinitely long and simply-supported along the long sides. Stiffeners are spaced at regular intervals, dividing the plate into a number of panels of uniform size. The effect of bending and torsional stiffnesses of the stiffeners upon the buckling shear stress is calculated for the complete range of stiffnesses, for panels with ratios of width to stiffener spacing of 1, 2 and 5. The results are presented in tabular and graphical forms.—(33.2.4.6.4).

The strength of tubes under uniform external pressure. P. C. Cleaver. C.P. 253. (1956).

This report traces the development of theoretical solutions to the problem of determining the strength of tubes subjected to uniform external pressure, and describes an extensive series of tests to check the accuracy of the Sturm solution to this problem and the effects of material properties of collapse pressure. A total of 530 tests were made covering ranges of length: diameter from 14·0 to 0·51 and nominal thickness: diameter from 0·0098 to 0·056.—(33.2.4.3.7).

Some fatigue characteristics of a two spar light alloy structure (Meteor 4 tailplane). K. R. Raithby and J. Longson. C.P. 258. (1956).

Results are given for fatigue tests on sixty-one Meteor tailplanes, treated as representative small-scale wing systems and tested under a variety of loading conditions. The object of the investigations was to study the fatigue characteristics of a typical aircraft structure, in particular the effects of mean load and alternating load on the endurance. The effects of preloading, periodic overloading and low temperatures were also investigated.—(33.2.3.4.10 × 31.2.4.3).

Thermal problems in aircraft structures. N. J. Hoff. AGARD Report 2. (*June* 1956).

A summary is given of problems in structural design and analysis of aircraft when high supersonic speeds cause elevated temperatures in the structure. Experimental methods and equipment being used by various U.S. research organisations are described.—(33.2.4.0.9).

Uber die Beulung anisotroper Plattenstreifen. W. Thielemann. D.V.L. Bericht Nr. 16. (*June* 1956).—(33.2.4.5).

Beitrag zur Frage der Beulung dünnwandiger axial gedrückter Kreiszylinder. W. Thielemann und H. J. Dreyer. D.V.L. Bericht Nr. 17. (*June* 1956).—(33.2.4.3.1).

Stress analysis of circular semimonocoque cylinders with cutouts. H. G. McComb. N.A.C.A. Report 1251. (1955).

A method is presented for analysing the stresses about cutouts in circular semi-monocoque cylinders with flexible

rings. The method involves the use of so-called perturbation stress distributions which are superposed on the stress distribution that would exist in the structure with no cut-out. The method can be used for any loading case for which the structure without the cut-out can be analysed and is sufficiently versatile to account for stringer and shear reinforcements about the cut-out.—(33.2.4.3).

The fatigue strength of riveted joints and lugs. J. Schijve. N.A.C.A. T.M. 1395. (*August* 1956).

Tests are reported on riveted joints and lugs for the primary purpose of comparing several types of riveted joints and to study the effect of various factors on the fatigue strength of lugs. A check was made to ascertain if an estimate of the fatigue life at a certain loading could be made from the dimensions of the joint and the fatigue data of the unnotched material. Recommendations are made on the proportioning of joints to obtain better fatigue behaviour.—(33.2.4.13.10 × 31.2.3.2.2).

On landing gear stresses. A. Gentric. N.A.C.A. T.M. 1422. (*July* 1956).

The French viewpoint is given on ground loads problems and their current efforts and new research equipment discussed. Some data are presented on tangential forces due to wheel spin-up effects and on longitudinal oscillations of landing gears. The subject of fatigue failures resulting from longitudinal oscillations is discussed and several case histories are presented. Overall suggestions for improvement in landing-gear design techniques are given and the areas where additional research is needed are indicated.—(33.2.3.5).

Compressive and torsional buckling of thin-wall cylinders in yield region. G. Gerard. N.A.C.A. T.N. 3726. (*August* 1956).

Based on assumptions which have led to the best agreement between theory and test data on inelastic buckling of flat plates, a general set of equilibrum differential equations for the plastic buckling of cylinders has been derived. These equations have been used to obtain solutions for the compressive and torsional buckling of long cylinders in the yield region. Test data are presented which indicate satisfactory agreement with the theoretical plasticity-reduction factors in most cases.—(33.2.4.3.6).

Bending tests of ring-stiffened circular cylinders. J. P. Peterson. N.A.C.A. T.N. 3735. (*July* 1956).

Twenty-five ring-stiffened circular cylinders were loaded to failure in bending. The results are presented in the form of design curves which are applicable to cylinders with heavy rings that fail as a result of local buckling.—(33.2.4.3.2).

Study of size effect in sheet-stringer panels. J. P. Doman and E. B. Schwartz. N.A.C.A. T.N. 3756. (*July* 1956).

An investigation was conducted to determine whether there are significant size effects in compressive strength of large Z-stiffened sheet-stringer panels as compared with geometrically similar smaller models and thus to ascertain whether the prediction of the strength of large panels by model tests is reliable. The specimens studied were manufactured from 7075-T6 aluminium alloy and included four representative types of panel designs, with full- and one-quarter-scale panels of each type.—(33.2.4.6.1 × 33.3.2).

A study of the efficiency of high-strength, steel, cellular-core sandwich plates in compression. A. E. Johnson and J. W. Semonian. N.A.C.A. T.N. 3751. (*September* 1956).

Structural efficiency curves are presented for high-strength, stainless-steel, cellular-core sandwich plates of various proportions subjected to compressive end loads for temperatures of 80° F. and 600° F. Optimum proportions of sandwich plates for any value of the compressive loading intensity can be determined from the curves. The efficiency of steel sandwich plates of optimum proportions is compared with the efficiency of solid plates of high-strength steel and aluminium and titanium alloys at the two temperatures.—(33.2.4.6.6).

Torsional instability of hinged flanges stiffened by lips and bulbs. G. Gerard. N.A.C.A. T.N. 3757. (*August* 1956).

Based on torsional instability theory, buckling charts are presented for determining the critical strain of hinged flanges stiffened by idealised lip and bulb elements.—(33.2.4.6.6).

Experimental investigation of the strength of multiweb beams with corrugated webs. A. F. Fraser. N.A.C.A. T.N. 3801. (*October* 1956).

The results of an experimental investigation of the strength of multi-web beams with corrugated webs are reported. Included in the investigation were two types of connection between the web and the skin. A comparison between the structural efficiency of corrugated-web and channel-web multi-web beams is presented, and it is shown that, for a considerable range of the structural index, corrugated-web beams can be built which are structurally more efficient than channel-web beams.—(33.2.4.1).

Fatigue-crack propagation in aluminum-alloy box beams. H. F. Hardrath et al. N.A.C.A. T.N. 3856. (*August* 1956).

Eighteen box-beam specimens constructed according to four designs were subjected to fatigue tests to study fatigue-crack propagation and accompanying stress redistribution. At least two specimens of each design were constructed from each of the aluminium alloys 2024-T3 and 7075-T6.—(33.2.4.1.10 × 31.2.3.3.1).

Testing—*see also* Theory and Analysis

An unconventional type of fatigue-testing machine. F. Aughtie and H. L. Cox. R. & M. 2833. (1955).

The general principles governing the design of fatigue-testing machines are considered, and the operation of a machine in which the range of load is generated by resonant oscillation of a mass on the end of a spring is examined. The advantages attendant upon such operation are demonstrated and a driving mechanism which ensures stable operation at the resonant frequency is described. The construction and operation of a direct-stress fatigue-testing machine embodying the principles of resonant oscillation are described and skeleton designs for a torsional fatigue-testing machine suitable for testing specimens 3 in. in diameter and for a direct-stress-fatigue testing machine to give a range of 50 tons are appended.—(33.3.1 × 31.2.1).

Aircraft structures research at elevated temperatures. J. E. Duberg. AGARD Report 3. (*September* 1955).

Test techniques developed and used at the N.A.C.A. are reviewed. Experimental results are presented and model scaling is discussed for testing of structures at high temperatures.—(33.3).

Weight Analysis and Control

Aérothermodynamique fondamentale et notions d'aérothermochimie. M. Roy. O.N.E.R.A. Publication No. 84. (1956).

Cet exposée de notions fondamentales fait dériver la Mécanique des mileux continus et déformables des principes mêmes de la Thermodynamique. La notion de rendement est ensuite discutée et commentée dans plusieurs cas d'application et le "rendement isentropique" d'un régime d'écoulement fluide est spécialement analysé. Les écoulements unidimensionnels sont ensuite traités, en considérant à la fois le cas de réactions chimiques et celui d'échanges thermiques au sein et à la frontière du milieu.—(33.4 × 1.9).

THERMODYNAMICS

See also Science General

A propos de quelques expériences récentes sur la convection de la chaleur et la transformation de l'énergie. P. Vernotte. Pub. Sc. et Tech. N.T. 61. (1956).

L'induction n'est pas une démonstration et les conséquences tirées de principes physiques n'ont qu'une portée physique. Application à la convection thermique par les fils et aux transformations masse-énergie, où une erreur de raisonnement a faussé les conséquences pratiques.—(34.3.2 × 32.2).

Étude expérimentale de la convection forcée sur paroi mobile (Hyperconvection Favre). C. Bory. Pub. Sc. et Tech. No. 312. (1956).

Etude de l'échange de chaleur entre un courant d'air et un cylindre dont une portion de la paroi est exposée au vent. Le coefficient de convection est mesuré pour plusieurs vitesses du vent; pour chacune de celles-ci une détermination est faite pour la paroi immobile et pour diverses vitesses de paroi obtenues en faisant tourner le cylindre autour de son axe.—(34.3.2).

Recherches sur la combustion d'un mélange d'hydrocarbures. J. Rappeneau. Pub. Sc. et Tech. 318. (1956).

La combustion du kérosène dans l'air est étudiée en déterminant les concentrations des produits de combustion, les températures atteintes et les rendements de combustion. Le calcul théorique de ces quantités précède l'étude expérimentale qui a été effectuée en utilisant comme foyer une chambre de combustion de turboréacteur. Pour mesurer les concentrations, une méthode d'analyse de gaz continue (précision 1 pour cent environ) a été mise au point, et pour repérer les températures, des sondes spéciales ont été réalisées. Les résultats obtenus ont permis d'expliquer le processus de combustion du kérosène dans la chambre.—(34.1.1)

Calculations of laminar heat transfer around cylinders of arbitrary cross section and transpiration-cooled walls with application to turbine blade cooling. E. R. G. Eckert and J. N. B. Livingood. N.A.C.A. Report 1220. (1955).

An approximate method for development of flow and thermal boundary layers in laminar régime on cylinders with arbitrary cross section and transpiration-cooled walls is obtained by use of Karman's integrated momentum equation and an analogous heat-flow equation. Incompressible flow with constant property values throughout boundary layer is assumed.—(34.3).

Theoretical and experimental investigation of heat transfer by laminar natural convection between parallel plates. A. F. Lietzke. N.A.C.A. Report 1223. (1955).

For the experimental work, parallel walls (one heated uniformly and the other cooled uniformly) were simulated by an annulus with an inner-to-outer diameter ratio near 1. The theoretical results are presented in equations for the velocity and temperature profiles and the ratio of actual temperature drop across the fluid to temperature drop for pure conduction.—(34.3.2).

Compressibility factor, density, specific heat, enthalpy, entropy, free-energy function, viscosity, and thermal conductivity of steam. L. Fano et al. N.A.C.A. T.N. 3273. (*August* 1956).

The N.B.S.-N.A.C.A. tables of thermal properties of steam are grouped together for convenient use. They include the compressibility factor, density, specific heat at constant pressure, enthalpy, entropy, free-energy function, viscosity, and thermal conductivity for the real gas and the specific heat, enthalpy, entropy, and free-energy function for the ideal gas. Conversion factors to frequently used units are given to facilitate use of the tables in dimensionless form. —(34.1).

Space heating rates for some premixed turbulent propane-air flames. B. D. Fine and P. Wagner. N.A.C.A. T.N. 3277. (*June* 1956).

Space heating rate measurements were made on Bunsen burner flames stabilised over a field of pipe-induced turbulence to yield information on the characteristics of turbulent combustion.—(34.1.1).

Effect of phosphate coatings on temperature of metal parts exposed to flame environments. G. C. Fryburg et al. N.A.C.A. T.N. 3279. (*July* 1956).

The effect of phosphate coatings on the temperature of metal specimens placed in a flame environment was investigated.—(34.1.1).

Drag coefficients for droplets and solid spheres in clouds accelerating in airstreams. R. D. Ingebo. N.A.C.A. T.N. 3762. (*September* 1956).

Linear accelerations for droplets and solid spheres (in clouds) in air streams were determined from sphere diameter and velocity data obtained with a high-speed camera developed at the N.A.C.A. Lewis laboratory.—(34.3).

Some effects of small-scale flow disturbance on nozzle-burner flames. E. L. Wong. N.A.C.A. T.N. 3765. (September 1956).

Wire grids were used as turbulence generators in a ½-inch nozzle burner. Hot-wire-anemometer equipment was used to measure the flow disturbance intensity in the cold flow with and without the grids in place.—(34.1.1).

List of Abbreviations

The following is a list of abbreviations used in the titles of the Reports:—

A.C.A.	Australian Aeronautical Research Committee.
AGARD	Advisory Group for Aeronautical Research and Development, Paris.
A.R.C.	Aeronautical Research Council, England.
A.R.C.	Aeronautical Research Committee, Australia.
A.R.L.	Aeronautical Research Laboratories, Australia.
B.S.I.	British Standards Institution.
C.A.A.	Civil Aeronautics Administration, U.S.
C. of A.	College of Aeronautics, England.
C.P.	Current Paper of the Aeronautical Research Council, Canada.
D.F.L.	Deutsche Forschungsanstalt für Luftfahrt, Germany.
D.V.L.	Deutsche Versuchsanstalt für Luftfahrt, Germany.
E.T.H.	Mitteilungen aus dem Institut für Aerodynamik Eidgenössischen technischen Hochschule (Zurich).
F.F.A.	Flygtekniska Forsoksanstalten, Sweden.
I.F.T.A.	Institut Français du Transport Aérien.
K.T.H.	Kungl Tekniska Hogskolan (Institutionen för Flygteknik), Sweden.
N.A.C.A.	National Advisory Committee for Aeronautics, U.S.
T.M.	Technical Memorandum.
T.N.	Technical Note.
N.A.E.	National Aeronautical Establishment, Canada.
N.L.L.	National Luchtvaartlaboratorium, Holland.
N.R.C.	National Research Council, Canada.
O.N.E.R.A.	Office National d'Études et de Recherches Aéronautiques, France.
Pub. Sc. et Tech.	Publications Scientifiques et Techniques du Ministère de l'Air, France.
R. & M. and C.P.	Reports and Memoranda and Current Papers of the Aeronautical Research Council, England.
S.A.A.B.	Svenska Aeroplan Aktiebologet, Sweden.
U.T.I.A.	University of Toronto, Institute of Aerophysics.
W.G.L.	Wissenschaftlichen Gesellschaft für Luftfahrt, Germany.